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Report of the International Ice Patrol Service in the North Atlantic Ocean

SEASON OF 1974

CG-188-29

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REPORT OF THE INTERNATIONAL ICE PATROL SERVICES IN THE NORTH ATLANTIC OCEAN

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FOREWORD

Forwarded herewith is Bulletin No. 60 of the International Ice Patrol describing the Patrol's services, and ice observations and conditions during the 1974 season.

N. C. VENZKE
Chief, Office of Operation

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PREFACE

This report is 60th in a series of annual reports on the International Ice Patrol Service in the North Atlantic Ocean. It contains information on Ice Patrol organization, communications and operations, on ice and environmental conditions and their relationship in 1974, on oceanographic conditions, Ice Patrol research and development, and evaluation of the Airborne Radiation Thermometer and Earth Resources Technology Satellite.

The authors of this report, Commander Albert D. SUPER, USCG and Lieutenant Douglas W. CROWELL, USCG acknowledge ice and weather data provided by the Canadian Department of the Environment, weather and oceanographic data provided by the U.S. Naval Weather Service, and oceanographic data provided by the U.S. Coast Guard Oceanographic Unit. Acknowledgement is also made to Yeoman Third Class Terry L. GEST, USCG, Marine Science Technican First Class Neil O. TIBAYAN, USCG, Marine Science Technician Second Class Raymond J. EVERS, USCG, Marine' Science Technician Second Class Raymond M. LARKIN, USCG, Marine Science Technician Second Class Robert N. HILDEBRAND, USCG, Marine Science Technician Third Class Paul A. LeBRUN, USCG, Marine Science Technician Third Class James M. GAYNOR, USCG, and Marine Science Technician Third Class Robert E. BLOHME, USCG, for illustrations for this report. A special acknowledgement is made to Lieutenant Junior Grade Stephen R. OSMER, USCG, who is responsible for most of the appendices to this report.

INTERNATIONAL ICE PATROL, 1974

The 1974 International Ice Service in the North Atlantic Ocean was conducted by the United States Coast Guard under the provisions of Title 46, United States Code, Section 738, 738a through 738d, and the International Convention for the Safety of Life at Sea, 1960, Regulations 5 through 8. The International Ice Patrol is a service for observing and disseminating information on ice conditions in the Grand Banks Region of the Northwest Atlantic Ocean. During the ice season, the southern and southwestern limits of the regions of icebergs in the vicinity of the Grand Banks of Newfoundland are guarded for the purpose of informing passing ships of the extent of this dangerous region. The International Ice Patrol also studies ice conditions in general, with emphasis on the formation, drift and deterioration of iceberges, and assists ships and personnel requiring aid within the limits of operation of the Ice Patrol forces.

The International Ice Patrol is directed from the Ice Patrol Office located on Governors Island, New York. The Ice Patrol Office gathers ice and environmental data from various sources, maintains an ice plot, forecasts ice conditions, prepares the twice-daily Ice Bulletin, replies to requests for special ice information, and executes operational control of the Aerial Ice Reconnaissance Detachment, the Ice Patrol Oceanographic cutter and the Surface Patrol cutter when assigned.

Vice Admiral Benjamin F. ENGEL, U.S. Coast Guard, was Commander, International Ice Patrol until July 1, 1974. After this date Vice Admiral William F. REA III, U.S. Coast Guard held this responsibility. Commander Albert D. SUPER, U.S. Coast Guard, was directly responsible for the management of the Patrol during the entire season.

Preseason flights were made in January, February and March, 1974. The Aerial Ice Reconnaissance Detachment was deployed to St. John's, Newfoundland on March 25 and returned to the United States on July 30, 1974. Several reconnaissance fights of opportunity were conducted in August in conjunction with other missions to determine final melt of bergs and season termination. This was the first time Ice Patrol utilized St. John's for its base of operations almost exclusively. Although the cost of both accommodations and aircraft fuel were higher then previous years' operations from Canadian Forces Base Summerside, Prince Edward Island, the reduced aircraft enroute time to the vicinity of the reconnaissance area resulted in a reduction in the amount of fuel required by the aircraft. Effective search duration on-scene was also enhanced.

The 1974 Ice Season officially commenced at 0000 GMT, March 21, when the first Ice Bulletin was issued, and continued until the final Bulletin was issued at 1200 GMT, August 13, 1974. The twice-daily Ice Bulletins were broadcast by the International Ice Patrol Communications Station Boston/NIK, U.S. Naval Radio Station Norfolk/NAM, Canadian Maritime Command Radio Station Mill Cove/CFH, and Canadian Coastal Radio Station St. John's/VON. A radiofacsimile ice chart was broadcast from Boston/NIK once each day . Iceberg information was also included on the regularly scheduled radiofacsimile broadcasts of Fleet Weather Central Norfolk/NFAX, CANMARCOM/CFH, Radio Bracknell/GFE, Radio Hamburg/DGC and Radio Pinneburg/DGN.

The U.S. Coast Guard Cutter EVERGREEN, commanded by Commander Martin J. MOYNIHAN, U.S. Coast Guard, conducted oceanographic and research cruises for the Ice Patrol from April 4 to May 9, and from June 4 to July 9. During these cruises, EVERGREEN occupied oceanographic stations along select Ice Patrol standard sections, made iceberg tagging and drift observations, took anchored current meter stations and evaluated expendable surface current probes. Approximately two days of the second cruise were devoted to iceberg reconnaissance for the southernmost bergs while enroute to her home port. With the iceberg concentrations south of 46° N relatively sparce, a Surface Patrol was not required this year.

During the 1974 Season an estimated 1386 icebergs drifted south of 48° N, the second heaviest season in Ice Patrol history.

AERIAL ICE RECONNAISSANCE

During the period September 1, 1973 to August 31, 1974 a total of 79 ice observation flights were flown. Preseason flights made in January, February and March accounted for 16 flights, and the remaining 63 flights were made during the ice season. The purpose of the preseason surveys was to study iceberg distribution patterns along the Labrador coast, off Baffin Island and in the Davis Strait and to evaluate the commencement and potentail of the developing ice season. The purpose of the regular season flights was to guard the southwestern, southern and southeastern limits of icebergs, to evaluate the short-term iceberg potential of the waters immediately north of the Grand Banks, and occasionally to study the iceberg distribution along the Labrador coast. The flight statistics shown in Table 1 do not include the flight time required to make the passages between U.S. Coast Guard Air Station, Elizabeth City, North Carolina and St. John's, Newfoundland for crew relief and aircraft maintenance.

Aerial ice reconnaissance was accomplished by U.S. Coast Guard HC–130B (Lockheed Hercules) four-engine aircraft from the Coast Guard Air Station at Elizabeth City, North Carolina. During the iceberg season, the aircraft operated out of Torbay Airport, St. John's, Newfoundland almost exclusively.

On March 25, the Ice Reconnaissance Detachment deployed to St. John's from Elizabeth City. The main base remained at St. John's until July 30, when the Detachment returned to the United States.

TABLE 1.—Aerial Ice Reconnaissance Statistics SEPTEMBER 1973 TO AUGUST 1974

Month	*Number of Flights*	*Flight Hours*
PRESEASON		
September—December	0	0
January	6	31.2
February	6	35.2
March	4	27.0
Preseason Total	16	93.4
REGULAR SEASON		
March	2	11.5
April	10	61.8
May	15	78.9
June	15	70.0
July	19	106.3
August	2	11.6
Regular Season Total	63	340.1
Annual Total	79	433.5

COMMUNICATIONS

Ice Patrol communications included receiving reports of ice and environmental conditions, transmitting Ice Bulletins and a daily facsimile chart, and the administrative and operational traffic necessary to the conduct of the Patrol. The Ice Bulletins were sent by teletype from the Third Coast Guard District Communications Center in New York to over 30 addressees, including those radio stations broadcasting the Bulletin. These stations were the U.S. Coast Guard Communications Station Boston/NIK/NMF, U.S. Naval Radio Station Norfolk/NAM, Canadian Coastal Radio Station St. John's/VON and Canadian Forces Maritime Command Radio Station Mill Cove/CFH.

Coast Guard Communications Station Boston transmitted the Ice Bulletin by CW at 0018 GMT on 5230 and 8502 kHz and at 1218 GMT on 8502 and 12750 kHz. After a 2-minute series of test signals the transmissions were made at 25 words per minute and then repeated at 15 words per minute. Coast Guard Communications Station Boston/NIK also transmitted a daily radiofacsimile broadcast depicting the locations of icebergs and sea ice at 1600 GMT simultaneously on 8502 and 12750 kHz at a drum speed of 120 revolutions per minute.

Ice Bulletins were also broadcast twice daily by U.S. Naval Radio Station Norfolk/NAM at 0430 and 1700 GMT on 88.0 (except the Tuesday 1700 GMT transmission was made on 134.9 kHz), 5870, 8090, 12135, 16180, 20225 (1700 GMT only) and 25590 (1200 GMT only) kHz; Canadian Maritime Command Radio Station Mill Cove/CFH at 0130 and 1330 GMT on 438 (except the 1330 GMT transmission the second Thursday each month), 4356.5, 6449.5, 8662, 12984, 17218.4 and 22587 (on request) kHz; and Canadian Coastal Radio Station St. John's/VON at 0000 and 1330 GMT on 478 kHz.

Radiofacsimile broadcasts that included the limits of icebergs were also made by Fleet Weather Central Norfolk/NFAX at 0320 and 1520 GMT on 4957, 8080, 10865, 16410 and 20015 kHz; Canadian Maritime Command Radio Mill Cove/CFH at 0000 and 1200 GMT on 133.15, 4271, 9890, 13510 and 17560 kHz; Radio Bracknell/GFE at 1400 GMT on 4782, 9203, 14436 and 18261 kHz; and Radio Hamburg/DGC and Pinneburg/DGN at 0905 and 2145 GMT on 3695.3 and 13627.1 kHz, all at drum speed 120.

Special broadcasts were made by Canadian Coastal Radio Station St. John's/VON as required when icebergs were sighted outside the limits of ice between regularly scheduled broadcasts. These transmissions were preceded by the International Safety Signal (TTT) on 500 kHz.

Merchant ships calling to transmit ice sightings, weather and sea surface temperatures were requested to use the regularly assigned international call signs of the Coast Guard Ocean Stations, East Coast AMVER Radio Stations, or Canadian Coastal Radio Station St. John's/VON. All Coast Guard Stations were alert to answer NIK/NIDK calls, if used.

Ice information services for the Gulf of St. Lawrence, as well as the approaches and coastal waters of Newfoundland and Labrador, were provided by the Canadian Ministry of Transport from December until approximately late June. Ships obtained ice information by contacting the Ice Operations Officer, Dartmouth, Nova Scotia via Sydney Marine Radio/VCO or Halifax Marine Radio/VCS.

Communications statistics for the period September 1, 1973 through August 31, 1974 are shown in Table 2.

TABLE 2.—COMMUNICATIONS STATISTICS

Number of ice reports received from ships	540
Number of ships furnishing ice reports	178
Number of ice reports received from commerical aircraft	4
Number of sea surface temperature reports	919
Number of ships furnishing sea surface temperature reports	59
Number of ships requesting special ice information	77
Number of NIK Ice Bulletins issued	292
Number of NIK facsimile broadcasts	146

There were twelve outstanding contributors of iceberg sighting reports and special sea surface temperature observations to the Ice Patrol. These ships were:

USCGC HAMILTON/NMAG
M/V ATLANTIC SPAN/SLPN
M/V BAKAR/LFSW
USCGC CHASE/NLPM
M/V BANIJA/YTEK
M/V BENEDETTA F/ICIB
USCGC MORGENTHAU/NDWA
M/V BOCKENHELM/DDNQ
M/V LIVANITA/JXRN
USCGC EDISTO/NIQU
USCGC WESTWIND/NLKL
M/V MANCHESTER ZEAL/GSED

ICE CONDITIONS, 1974 SEASON

September—December 1973

After the close of the 1973 Ice Patrol Season, occasional icebergs continued to drift south along the Labrador coast. In September only one iceberg report was received, that of a small berg in the Strait of Belle Isle. Sea ice conditions were normal over Baffin Bay and Davis Strait with freeze-up starting in the extreme north of Baffin Bay during the third and fourth weeks of September. In October and November, there were numerous reports of icebergs in the Strait of Belle Isle, its approaches, and northward to Hamilton Inlet. The southernmost of these was a small berg at 50° 48′N 57° 47′W at the Strait's western approach. The sea ice developed very slowly during October, but by the end of November, it had slightly exceeded its normal limits in Baffin Bay. There were no iceberg reports received in December. The slight excess of sea ice was maintained in Baffin Bay while the ice formation off the Labrador coast progressed slower than normal.

January 1974

There were no icebergs reported to the Ice Patrol office by maritime traffic in January. During the first week, new and grey ice formed south of 51°N, extending into Notre Dame Bay with some drifting around Cape Freels to near 49°N. The heavier Labrador pack ice advanced to 52°N. A preseason survey was conducted January 6–15 along the Labrador and Baffin Island coasts and across Davis Strait. The flight tracks and observed icebergs are shown in figure 1. Only a few icebergs were observed south of 56°N, about normal concentrations from 56°N to Cape Chidley, Labrador, and much above normal concentrations along the Baffin Island coast to north of Cape Dyer and across Davis Strait. Of significance were two icebergs (a small and a medium) just off the Newfoundland coast near Cape Freels. This was the first time the Baffin Island coast from Cape Dyer to Cape Christian was investigated as part of the January preseason survey. The latitudinal distribution of icebergs is illustrated graphically in Figure 2. By the end of January a large excess of sea ice developed over the Davis Strait and off Labrador and Newfoundland. New and grey ice had progressed as far south as 47° 30′N and as far east as 49° 18′W. Open water remained along the Avalon Peninsula to Cape Bonavista, but generally close pack new and grey ice lay in the coastal approaches to Notre Dame Bay.

February 1974

During the first half of February only two icebergs were reported, both over 400 miles off the coast of Labrador. There was a rapid south-southeastward spread of pack ice off Newfoundland so that by mid-month it extended as far south as 46° 10′N 52° 30′W and as far east as 47°W. The extent of pack ice returned to normal over Davis Strait and along the coast of Labrador. Offshore drift prevented any significant intrusions into east Newfoundland coastal areas. In eastern Notre Dame Bay very close pack white and grey-white ice developed, while lighter conditions were the rule for the western sections of the Bay. This month's preseason survey, conducted February 19 through March 1, revealed three times the usual iceberg population south of Cape Chidley, Labrador. This was also the first time the southern Baffin Island coast and Davis Strait were surveyed during February. A total of 2403 icebergs were located from the Davis Strait southward. The flight tracks and iceberg concentrations are shown in figure 3 with the latitudinal berg distribution displayed graphically in figure 4. The sea ice edge retreated rapidly during the last two weeks of February so that by the end of the month the southern limit was lying east of St. John's with a tongue of light sea ice extending eastward over the northern Grand Banks. The computer drift of a medium iceberg reported in position 48° 28′N 46° 28′W on February 24 had it south of 48°N by the end of the month, the first iceberg of the season.

March 1974

With no additional icebergs reported to the Ice Patrol office in early March, an additional preason survey was conducted March 12–15. The flight tracks and observed icebergs are shown in Figure 5. The southernmost berg during this survey was at 47°20′N 46°14′W with one additional berg south of 48°N. Twenty-nine icebergs and many growlers were sighted between 48°N and 49°N; fifty-one bergs and many growlers between 49°N and 50°N. On the basis of these flights, computer ice drifts and an analysis of actual and predicted pressure patterns, the first bergs were estimated to drift south of 46°N by March 21, thus Ice Patrol services commenced that date. Ice Patrol forces were deployed to St. John's, Newfoundland on March 25. Sea ice conditions were normal over Davis Strait during March with a slight deficit off the Labrador coast. The southern edge of the pack remained between 47°N and 48°N through mid-March. The heavier pack ice remained well offshore, and at the end of the month, the southern limit extended eastward from St. John's very similar to its position at the beginning of the month. Figure 6 shows these sea ice conditions along with the southernmost iceberg of the month at 45°36′N 43°25′W. After a good reconnaissance flight by the Ice Patrol aircraft on March 30, together with the computer drift of the preseason iceberg survey, 99 icebergs were estimated to have drifted south of 48°N during the month.

April 1974

Good reconnaissance flights on April 3 and 4 located almost 100 icebergs and over 50 growlers between 47°N and 49°N. These are shown in figure 7. During the first half of April, the approaches to St. John's remained open and the ice edge began its seasonal northward retreat. At mid-month, 421 icebergs and 111 growlers were located as shown in figure 8. The tongue of sea ice north of the Grand Banks area changed little, if any, during the rest of the month. Towards the end of April, 148 icebergs and 47 growlers were located in the vicinity of 48°N and east of Flemish Cap as shown in figure 9. The southernmost and eastermost icebergs for the month occurred on April 30 at 44°31′N 46°07′W and 46°40′N 40°17′W, respectively, as shown in figure 10. The southernmost was some 250 miles north of its position during April of last year, thus indicating a surface patrol may not be necessary. It was an extremely heavy month, however, with an estimated 345 icebergs drifting south of 48°N. The tongue of sea ice north of the Grand Banks area changed little, if any, by the end of the month. The edge of open pack ice extended as far south as 46°15′N and as far east as 47°W.

May 1974

On the first of May a good flight covering the northern Grand Banks and Flemish Cap revealed 72 icebergs and 31 growlers, then on the fourth, a flight north of this area revealed an additional 161 icebergs, 40 growlers and 115 radar targets. These are shown in figure 11. Also on May 4, the edge of sea ice reached 47°N 45°40′W. By May 10, the tongue had disappeared, leaving no sea ice south of 58°N. North of about 55°N, however, a new excess of sea ice was apparent. Flights on May 10, 12 and 13 (figure 12) revealed a total of 740 icebergs, an indication that this was not going to be just a heavy year, but one of the heaviest years in Ice Patrol history. On May 15, the easternmost iceberg of the month was at 47°52′N 37°55′W as shown in figure 13. By the end of the month, the eastern limits of sea ice had continued to decrease, however, the southern limit remained in the vicinity of Baccalieu Island. The southernmost berg of the month, as depicted with the ice conditions in figure 14, was 130 miles north of the southernmost iceberg positions during the same month last year. Thus any apprehension of requiring a surface patrol was abated. An estimated 446 icebergs drifted south of 48°N during the month.

June 1974

On the first of June, 121 icebergs and 43 growlers were located on the northern Grand Banks and Flemish Cap. Then on June 2, the area southeast of Flemish Cap was investigated, searching for icebergs previously reported by ships. The visibility was excellent, but nothing was sighted indicating that the bergs had already melted. These flights are shown in figure 15. Early in the month sea ice remained in Conception and Trinity Bays and northwest along the coast approximately 60 miles offshores. The easternmost iceberg of the season was in position 49°25′N 37°53′W on June 10. The ice condi-

tions on this date are displayed in figure 16. On June 18 a coastal and northern flight from south of the Avalon Peninsula to just south of Hamilton Inlet revealed over 800 icebergs, a very significant number for the remainder of the season. Poor on scene visibility limited the effectiveness of the remainder of the flights this month. Based on computer drift, the southernmost iceberg of the season was in position 41°24′N 48°10′W on June 25. The ice conditions on this date are shown in figure 17. An extensive belt of sea ice remained along the coasts of Labrador and Newfoundland which are normally clear by the end of June. It was estimated that 266 icebergs drifted south of 48°N during the month.

July 1974

On July 6, a coastal flight located 39 icebergs east and south of the Avalon Peninsula. On the following day a good flight covered the eastern slope of the Grand Banks revealing only 16 icebergs. These are shown in figure 18. The Strait of Belle Isle was clear of sea ice on July 12, except for patches along the northern shore. Only a few patches of sea ice remained along the northeast coast of Newfoundland, and these rapidly disappeared. Another coastal flight at mid-month revealed almost 100 icebergs northeast and east of the Avalon Peninsula. There was persistent fog on the Grand Banks for the next two weeks with all aircraft reconnaissance failing to detect anything but radar targets. Good flights were finally obtained on July 29 and 30 (figure 19) locating two small icebergs east of the Tail of the Banks with the next southernmost bergs in the vicinity of 47°N. A total of only 13 icebergs and one growler were sighted. Thus, the Ice Reconnaissance Detachment returned to New York and North Carolina on July 30. The July estimate of bergs south of 48°N was still 168, some ten times the monthly normal and brought the season count to over 1300 icebergs with one month remaining. Also, at the end of the month, over 100 icebergs were reported in the Strait of Belle Isle with over 50 bergs in its eastern approaches.

August 1974

Ship reports of the southernmost and easternmost icebergs persisted so ice observers were deployed with a Coast Guard C–130 logistics mission to Dakar, Senegal. One flight was conducted enroute St. John's on August 8, with a dedicated survey on the following day. As shown in figure 20, one iceberg and three growlers were located near the Tail of the Banks with 80 icebergs north of 47° 25′N and concentrated between 48°N and 49°N. The return flight from Dakar located the remains of two small rapidly melting pieces of ice on August 12 in positions 46° 15′N 46° 25′W and 46° 08′N 46° 53′W. These were estimated to melt completely within the next day. Thus, Ice Patrol services for the 1974 Season were terminated on August 13, with a minimal threat of icebergs south of 47°N. Many icebergs were reported during the remainder of the month in the eastern approaches to the Strait of the Belle Isle and a few just west of Flemish Cap after the season closed. It was estimated than an additional 61 icebergs drifted south of 48°N during the month of August bringing the season total to 1386, the second heaviest on record.

Table 3—ESTIMATED NUMBER OF ICEBERGS SOUTH OF LATITUDE 48 N, SEASON 1974

	Sept	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*May*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Total*
1974	0	0	0	0	0	1	99	345	446	266	168	61	1386
TOTAL 1946–1974	9	2	4	11	64	237	994	2916	2810	1711	480	100	9338
AVERAGE 1946–1974	0	0	0	0	2	8	34	100	97	59	17	3	322
TOTAL 1900–1974	255	109	110	91	184	688	3096	7761	9893	5229	1676	489	29,581
AVERAGE 1900–1974	3	1	1	1	2	9	41	103	132	70	22	7	394

OCEANOGRAPHIC CONDITIONS, 1974

R. W. Scobie

(U.S. COAST GUARD OCEANOGRAPHIC UNIT)

During the 1974 Ice Patrol Season, two oceanographic cruises (April 2—May 9 and June 4—July 9) were conducted in the vicinity of the Grand Banks aboard CGC EVERGREEN (WAGO–295). The primary purpose of these cruises was to provide Commander, International Ice Patrol (CIIP) with current data which could be utilized in forecasting the drift of icebergs threatening North Atlantic shipping. The secondary purpose was to conduct research projects relating to Ice Patrol. One of these projects was designed to determine how icebergs are affected by wind and ocean currents, while another project consisted of measuring deep ocean currents.

Surface currents were calculated from salinity and temperature data collected with a Salinity, Temperature, Depth Environmental Profiling System (STD). STD casts were taken along standard Ice Patrol sections to a depth of 1000 meters in deep water and to as close to the bottom as practicable in the shallower water along the continental slope. All STD data were processed real–time aboard ship using a Digital Data Logger/Computer arrangement and were subsequently transmitted to CIIP.

Dynamic topography charts were produced from STD data and are presented here. To maintain synopticity, each chart represents half of one cruise. The Labrador Current, as usual, was flowing along the eastern edge of the Grand Banks during the first part of the first cruise (figure 21). The dynamic trough east of the Labrador Current is wider than normal and very flat. The steep gradient across the North Atlantic Current can be seen in the southeast portion of the survey area.

The survey conducted during the second part of the first cruise (figure 22), was an abbreviation of the survey conducted earlier in April. It appears that no significant changes occurred to the dynamic topography between these two surveys. The counterclockwise flow, which normally appears around Flemish Cap, was located below Flemish Cap during the second survey.

By the first half of the second cruise (figure 23), the dynamic topography had returned to nearly normal conditions and the gradients in the North Atlantic Current meander were not as steep as expected. Similar conditions were also observed during the second half of the second cruise (figure 24).

Iceberg tagging and tracking experiments were conducted twice (Aril 20—24 and June 20—29) during the Ice Patrol Season. The first experiment proved to be of only limited value primarily due to severe weather conditions. The second study was more successful with six icebergs being tracked; one of these icebergs was tracked for four days and nearly 100 miles.

A deep subsurface current meter array, which had been set at 44° 42.6′U, 48° 58.0′W from CGC EDISTO (WAGB–284) on February 11, 1974, was recovered on April 8. That array was replaced the same day by a similar array which was recovered on June 12. On June 13, a third array was set at 44° 40′N, 48° 59′W. Plans have been made to recover this array during the 1975 Ice Patrol Season. All these current meters were set to test the validity of using the 1000 decibar surface as a reference level for dynamic calculations.

More complete analysis of the STD data and results of the research projects will be reported in the U.S.C.G. Oceanographic Report Series (CG 373).

DISCUSSION OF ICEBERG AND ENVIRONMENTAL CONDITIONS

1974 ICE SEASON

The 1974 Season total of 1386 icebergs south of 48°N was the second heaviest in Ice Patrol history, surpassing the 1929 count of 1329. Of almost equal historical significance is that never before had there been three very heavy years in succession, that of 1584 icebergs during the 1972 Season and 947 during 1973. In attempting to explain the severity of the 1974 Season, the environmental factors, including the number of icebergs available to drift south of 48°N, the strength and duration of the northwesterly winds that help produce southerly iceberg transport, the sea ice cover that protects the icebergs, the development of the Labrador Current features (discussed in the Oceanographic Conditions, 1974 section), and the deterioration of icebergs are analyized in the following paragraphs.

During the January preseason flight a total of 1281 icebergs were sighted as shown in figure 1. Almost 600 of these bergs were counted by extending the survey area northward to Cape Christian, but it was still over a hundred bergs shy of the season total. Either of two suggestions are offered: the environmental conditions were extreme allowing for icebergs to drift from north of Cape Christian to south of 48°N or, East Greenland icebergs provided a more significant input to the seasonal berg total by drifting westward across the northern Labrador Sea and the Davis Strait. The February preseason survey totaled 2403 icebergs, as shown in figure 3, providing a reasonable explanation for its extremely heavy year and still allowing for berg casualties on the 1000 plus mile journey down the coast of Labrador into the Grand Banks area. In both January and February a large number of icebergs were located in the middle of the Davis Strait. As will be shown in the environmental conditions, icebergs from both north of Cape Christian and southeast of Davis Strait had the potential to move into the area between the January and February surveys.

Figures 26a through 26h show the normal and the 1974 surface pressure patterns for January through August. Because the January preseason survey revealed only three icebergs south of 56°N, those off Hamilton Inlet, it was not deemed necessary to analyze any of the prior months. The mean pressure pattern for January 1974 was dominated by the Icelandic Low, located 60°N 27°W, with a pressure of 973 mb. With the normal of almost 1000mb, a 27-mb anomoly was centered in the Low. Not only was the Icelandic Low more intense, the Azores High was higher in pressure at 1027 mb, and covered more area in the east-west direction. Thus the winds along the Baffin Island and Labrador coasts were extreme northerlies, possibly even a record, and provided for maximum iceberg southerly drift. Thus, the increased berg count in the February over the January survey can be accounted for.

The February 30–day mean pressure pattern was near normal in configuration, but the Icelandic Low, although recovering to 993 mb, was still over 10-mb lower than normal and displaced some 400 miles east of its usual position. The Azores High was normally located, but at 1025 mb it was 4 mb higher than usual. Thus, compared to January, the anomalies were small, but there was still a significant negative 9-mb anomaly off Labrador with an anomalous trough over Newfoundland. This enhanced the transport of icebergs across the Davis Strait and south along the Labrador coast.

The March mean pressure pattern was normal in appearance like February, but the central pressures were more extreme. The Icelandic Low at 993 mb was more than 12 mb deeper than usual and located 100 miles south of Kap Farvel, slightly west of its normal position. With the Azores High 5 mb higher than normal, major

departures were evident, especially over Baffin Bay and along the coast of Labrador (negative anomolies of 11 mb and 13 mb, respectively).

April brought a return to near-normal patterns and pressures with the Icelandic Low at 1003 mb only 4 mb below normal and located at its normal position southwest of Kap Farvel. The Azores High at 1025 mb was only 4 mb higher than usual and about 5° west of its normal location. Thus the winds were more northerly over the Labrador coast and about the usual magnitudes.

The May mean pressure pattern was more intensive than normal with the difference between the Icelandic Low and the Azores High more than usual. They were both in their usual positions providing for the same wind directions but larger magnitudes than normal.

In June, for the first time this year, the differences between the Icelandic Low and Azores High were less than normal. The June Icelandic Low was at its normal pressure but was relocated near 55°N 43°W rather than over the Labrador coast and had a second center over Iceland. The Azores High was in its usual position near 33°N 38°W and about 2 mb lower than normal. The departures from normal were thus small and confined to a positive 4 mb anomoly off the Labrador coast

The July Bermuda-Azores High closely resembled its usual features with the pressure pattern off the Labrador and Newfoundland coasts being mirror-images of the normal. In August the mean pressure pattern intensified with the Bermuda-Azores High 2 mb higher than normal and the 1005-mb Icelandic Low over 5 mb lower than normal. The High over the Greenland Ice Cap was 5 mb higher than normal at 1018 mb. The resulting greater than normal northwesterly winds had little effect on the rapidly closing Ice Season.

To determine and assign numerical values to the existing wind conditions, surface pressure gradients (differences in atmospheric pressure along a geographically orientated line) may be used. Six such gradients are defined in figure 27. From an analysis of these gradients, inferences can be made as to the northwesterly winds producing southerly iceberg drift, accentuating the Labrador Current, reducing the air and sea temperatures, and spreading and developing sea ice along the coasts of Labrador and Newfoundland.

Gradients 1 and 2 measure the winds of the coast of Labrador which are important in setting up the drift for transporting icebergs to the general area northeast of Newfoundland. Gradient 3 measures the wind component which assists or impedes icebergs as they drift along the eastern slope of the Grand Banks. Gradient 4 is a measure of the influence of westerly (or easterly) winds along the northern slope of the Grand Banks. This latter gradient is important in determining iceberg drift away from the Newfoundland coast and into the core of the Labrador Current. If the winds are too strong (or persistent) when the bergs reach the northeast corner of the Grand Banks, they may be carried out over Flemish Cap and into the warm waters of the North Atlantic Current. Gradients 5 and 6 provide a preseason indication of potential iceberg drift south and west in the Davis Strait, respectively.

The 1974 pressure gradient statistics are shown graphically in figure 27 in comparison with their 1946—1973 averages. Gradients 1 and 2 provide a tremendous impetus to southerly iceberg drift in January with almost three times the normal values, then after mid-February they display a continued above average value for the remainder of the season. Icebergs didn't reach the area of pressure gradients 3 and 4 until early March. From then until mid-June Gradient 3 averaged slightly negative while Gradient 4 slowly diminished from over three times its normal value to slightly above normal. These gradients clearly show very little, if any, southerly iceberg drift potential once the iceberg reached the northern Grand Banks region, and explain why that, in spite of the excessive number of bergs, a surface patrol was not required. The predominent westerly winds shown in gradient 4 kept most of the icebergs out of the influence of the main Labrador current drifting east over the Flemish Cap area and limiting only a few bergs to the region of the Tail of the Banks in June, relatively late in the season when the waters are showing major warming trends. Gradients 5 and 6 show large deviations form normal in the critical January through March time frame in the Davis Strait area. Thus extra impetus was provided to icebergs moving south through the Strait as well as westward across it.

Air temperatures along Baffin Island averaged about normal while those along the Labrador and Newfoundland coasts were much below normal throughout the winter and spring, and well into the summer months, as shown in figure 29. The locations of the stations monitored are shown in figure 27. A frost degree day, as used in figure 29, is defined as one day mean temperature of one Fahrenheit degree below 32° (e.g., one day at 20°F would be 12 frost degree days). Similarly, a melting degree day is one day mean temperature of one Fahrenheit degree above 32°. All stations had a below normal frost degree day accumulation at the end of December. By the end of January, the Newfoundland and Labrador stations had surpassed their respective normals and made rapid accumulations through the early spring. The melting degree accumulations for the remainder of spring and for the entire summer lagged significantly behind normal. Iceberg deterioration can thus be inferred to be less than normal allowing a greatly retarded mortality rate among the bergs destined for the Grand Banks, and an extension of the season of at about a month past its normal termination in mid-July.

These same environmental conditions described above produced a greater and more persistent sea ice cover as discussed in the section on Ice Conditions, 1974 Season. This provided protection to the bergs from sea state erosion through a greater portion of their journey and particularly influenced the larger counts south of 48°N latitude in the second half of the season. Collaterally, sea surface temperatures were lower than normal in the vicinity of the Grand Banks throughout the season.

RESEARCH AND DEVELOPMENT, 1974

During the spring of 1974, responsibility for International Ice Patrol research and development was transferred from the Coast Guard Oceanographic Unit, Washington, D.C. to the Coast Guard Research and Development Center, Groton, Connecticut. These tasks include iceberg detection and tracking, drift and prediction, deterioration, destruction, and production.

During the Ice Patrol cruises of USCGC EVERGREEN, an "Iceberg Tagging and Tracking Project" was conducted. The interim report by R. W. Scobie and R. M. Hayes of the Coast Guard Oceanographic Unit and R. Q. Robe of the Coast Guard Research and Development Center is included as Appendix A to this Bulletin.

Later during the summer, USCGC EDISTO conducted a "Labrador Coast Oceanographic Survey". A summary is included in this Bulletin as Appendix B. EDISTO also conducted iceberg studies in July and August 1974 in the Labrador Sea and Baffin Bay under the direction of R. Q. Robe of the Coast Guard Research and Development Center. These projects investigated the relationship of iceberg heights to drafts and total mass determinations relative to above surface dimensions. They will be reported in subsequent Ice Patrol Bulletins.

Also included in this Bulletin are evaluations of the Airborne Radiation Thermometer and the Earth Resources Technical Satellite, both by LTJG S. R. OSMER, USCG as Appendices C and D, respectively.

ICE AND SEA SURFACE TEMPERATURE REPORTS RECEIVED FROM SHIP'S OF PARTICIPATING NATIONS DURING 1974

BEGIUM

	ICE	SST
CHERTAL	1	
FEDERAL SCHELDE	1	
FINA AMERICA	1	1
FRUBEL OCEANIA	1	
MINERAL SERAING	1	1

CANADA

	ICE	SST
BAFFIN	3	
CAPE FREELS	5	
CARINO	1	
GULF CANADA	1	
IMPERIAL ACADIA	2	
KAKAWI	1	
GREAT BRITAIN	1	

DENMARK

	ICE	SST
"HOLLAND"	1	
INGE MAERSK	1	

FINLAND

	ICE	SST
GERMUNDO	1	1
GRERERSO	2	
KEPPO	1	
MALTESHOLM		3

FRANCE

	ICE	SST
ATLANTIC CHAMPAGNE	2	1
ATLANTIC COGNAC	1	
CATHERINE	3	1
CETRA LYRA	1	
FRANCE	3	1
MONT LOUIS	2	
ONDINE	1	
PENQUER	3	
ZELANDE	1	

FEDERAL REPUBLIC OF GERMANY

	ICE	SST
ALSTER EXPRESS	2	
ANA LUISA		2
BOCKENHEIM	15	
BORHEIM	3	
BRUNSBUTTEL		3
BUNTENSTEIN	2	
EBERHARDT ESSBERGER	1	
ELBE EXPRESS	4	
ERLANGEN		
FAROS	1	3
GAMMAGAS	2	
INO-A	2	1
JOHANN SCHULTE	1	
LEO SCHROEDER	1	
LEVERKUSEN	7	1
MELLUMERSAND	3	3
MOSEL EXPRESS	2	
MUENCHEN	3	
PROSERPINA	3	7
SAARLAND	1	
WESER	3	
WESER EXPRESS	1	
WESERMUNDE	1	
WIDAR	1	1
ZIM TOKYO	1	

GREAT BRITAIN

	ICE	SST
ANGLIA TEAM	1	1
ASIA GREIGHTER	1	
ATLANTIC CAUSEWAY	1	
ATLANTIC CITY	1	
AVON FOREST	1	
"BAMBURGH" CASTLE	1	
BEECHWOOD	1	
BENIHANT		3
BERNES	1	
BRIMNES	1	
CAMERONIA	1	
CAPE NELSON	1	
CAST BEAVER	6	
CHEVIOT	1	
CP AMBASSADOR	2	
CP DISCOVERER	6	
CP TRADER	2	

	ICE	SST
GREAT BRITAIN—Continued		
CP VOYAGEUR	8	
DART AMERICA	2	
DART ATLANTIC	4	1
DUKESGARTH	3	
FINNAMORE MEADOW	6	
H1070	1	
IDA LUNDRIGAN	1	
KING WILLIAM	1	
LONGSTONE	1	
MANCHESTER CONCORDE	5	
MANCHESTER COURAGE	7	1
MANCHESTER CRUSADE	4	
MANCHESTER QUEST	3	1
MANCHESTER ZEAL	4	8
MONKSGARTH	2	
MORANT		1
NEWFOUNDLAND COAST	1	
OCEAN SHORE	1	
ORBITA	1	
QUEEN ELIZABETH	3	
QUEENSGARTH	4	2
TROLL PARK	3	
WILTSHIRE	1	1
GREECE		
ANNOULA	1	
ANTHENIAN HORIZON	2	
ATLANTIC CHAMPION	2	
EFTYCHIA	1	
GRECIAN LIGHT	1	
IRINI	1	
LADY ERA	3	3
LIBRA	1	1
NORTH HIGHNESS		2
OCEAN MARINER	1	
POUKOU	1	
ITALY		
BENEDETTA F.	8	9
ELISA F.		3
JAPAN		
TOEI MARU	2	4
LIBERIA		
CAPE CANAVERAL	1	
CAPETAN GIORGIS	2	2
CARLANTIC	1	
DARIEN		4
DOBERG	1	1
HARRY C. WEBB	2	
MOZART	1	1
NESTOS	1	
NEW ENGLAND HUNTER	1	
NEW ENGLAND TRAPPER	1	
OGDEN EXPORTER	5	
PANETOLIKON	1	
PENNY MICHAELS	1	
NETHERLANDS		
HOLENDRECHT	2	
NEDLLOYD DELFT		8
NORWAY		
AUSTANGER	1	
BAKAR		33
CANTO	1	
CARMENCITA		5
FERDALE	1	1
HAVDRILL OIL RIG	4	
IDEFJORD	3	
KRISTIN BROVIG	1	
LIANA	1	
LIVANITA	15	
MOS GULF	1	
NORSE CAPTAIN	1	8
SAGAFJORD	1	
VANESSA	2	
VISTAFJORD	2	
JOHAN E.	1	
PANAMA		
CARCASTLE	1	
HELENE ROTH	1	
LINDBLAD EXPLORER	1	
MESSENGER	1	1
TRADE STAR	1	
SPAIN		
ERMUA		1
MANUEL YLLERA	1	
SWEDEN		
ATLANTIC SPAN	6	31
GRIPSHOLM	1	
KUNGSHOLM	4	
MONT ROYAL	4	

	ICE	SST
UNITED STATES OF AMERICA		
AMERICAN ACCORD		2
AMERICAN ALLIANCE	2	
AMERICAN LEADER	1	
USNS MAUMEE	1	
PELICAN	2	2
PRAIRIE GROVE	1	
TRANSCOLUMBIA		1
U.S. COAST GUARD		
CGC BIBB	2	
CGC CAMPBELL	4	
CGC CHASE	17	12
CGC DUANE	2	
CGC EDISTO	12	1
CGC EVERGREEN	30	704
CGC GALLATIN	1	2
CGC HAMILTON	82	
CGC MORGENTHAU	17	
CGC WESTWIND	14	
YUGOSLAVIA		
BANIJA	12	16
BARANJA	1	
IDRIJA	3	
IVO VOJNOVIC	4	

APPENDIX A

ICEBERG TAGGING AND TRACKING PROJECT 1974

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INTRODUCTION

During the 1974 Ice Patrol Season the Coast Guard Research and Development Center and the Coast Guard Oceanographic Unit conducted an iceberg drift project aboard the Coast Guard Cutter EVERGREEN. This project provided average drift vectors for six icebergs in the Grand Banks of Newfoundland area over a period of three to six days. The results were forwarded to Commander, International Ice Patrol (IIP). Comparisons could then be made by IIP between the observed drift values and those predicted by computer model. Icebergs were tagged to allow for the surveillance of a number of bergs distributed over an area of up to 300 square miles. This also assured positive identification upon subsequent visits to obtain position fixes. In the past, attempts have been made to mark icebergs using dye, however, iceberg melting, rain, wave action, and iceberg rolling often caused the dye patches to be washed away. The complications involved in tagging a berg for future recognition center around the dynamic nature of an iceberg.

Icebergs near the Grand Banks normally melt rapidly. A berg's rate of decay was a function of its environment and internal structure. Deterioration was hastened by warm sea and air temperatures, as well as by rough seas. Rivulets of melting water were seen cascading down the sides of some icebergs creating large channels on the surface and often collecting in pools in the basin areas. Others of the drydock variety had wave cut embayments which concentrated wave forces and speeded deterioration. Large chunks of ice often calved off icebergs to accelerate their destruction. Instabilities, which resulted from deterioration, caused icebergs to pitch and yaw and in severe cases to roll over completely. In consequence of these dynamic changes, it was very difficult to put anything on, or attach any device to, an iceberg that would remain in position long enough to give positive identification over a significant time interval (i.e., about 5–7 days).

METHODS

During the International Ice Patrol 1974 season a method was tested for the relocation and differentiation of icebergs used in drift studies near the Grand Bank region. The bergs were surrounded by an array of floats (styrofoam cylinders) connected by buoyant line (polypropylene, 3/8″ diameter). The length of this line varied from 400 to 800m depending upon the size of the iceberg. A spar-type, buoyant RDF transmitter was included in the line circle. One hundred and eighty degrees from the transmitter was a spar buoy with a radar reflector for electronic detection and/or red flags for visual detection (Figure A-1). Each RDF transmitter had a different transmission frequency to permit positive identification independent of visual observation. The transmitters were located with an automatic direction finder mounted on the bridge. The antenna for this system was secured to the railing just forward of the bridge. Early attempts at locating the RDF transmitters using handheld receiving sets were frustrated by the apparent omnidirectionality of the signal at ranges closer than 3700m as well as directional ambiguity at greater distances.

The tagging arrays were deployed from the CGC EVERGREEN during April and June of 1974. This was accomplished by casting off a spherical float attached to one end of the line. The line was then paid out as the vessel steamed around the iceberg. The cutter closed on the float heading into the wind and retrieved the spherical float with a grapnel. The two ends of the line, each having eye splices and thimbles, were joined together with a shackle. The tethering ring of the RDF spar buoy was attached to the shackle and placed in the water. The iceberg, thus encircled, carried along its array as it drifted.

During the first cruise (April/May 1974) the iceberg tagging project was plagued with the difficulty of locating suitable icebergs for tagging (i.e., small enough size) in the survey area. Later a storm carried away the arrays from the icebergs that finally were tagged. This storm lasted about two days with winds reaching 38 kts and the sea increased to 16 feet. All three tagging arrays were carried away and only one was recovered. The line on the recovered array was broken in two places. One break occurred with such force that the ends of the line fibers were fused; there was no evidence of chafing. The other break appeared to be the result of chafing. Because of this, little useful drift data were obtained from the first cruise.

The second cruise, using similar arrays, met with greater success because of more favorable weather. The CGC EVERGREEN was able to track several icebergs in dense fog for nine days. However, the tagging arrays slipped repeatedly over or under the icebergs. This necessitated early recovery of the equipment, which drifted away from the berg although the line circle had remained intact. This result was completely unexpected and probably resulted from the iceberg snagging the line and rolling out of the loop.

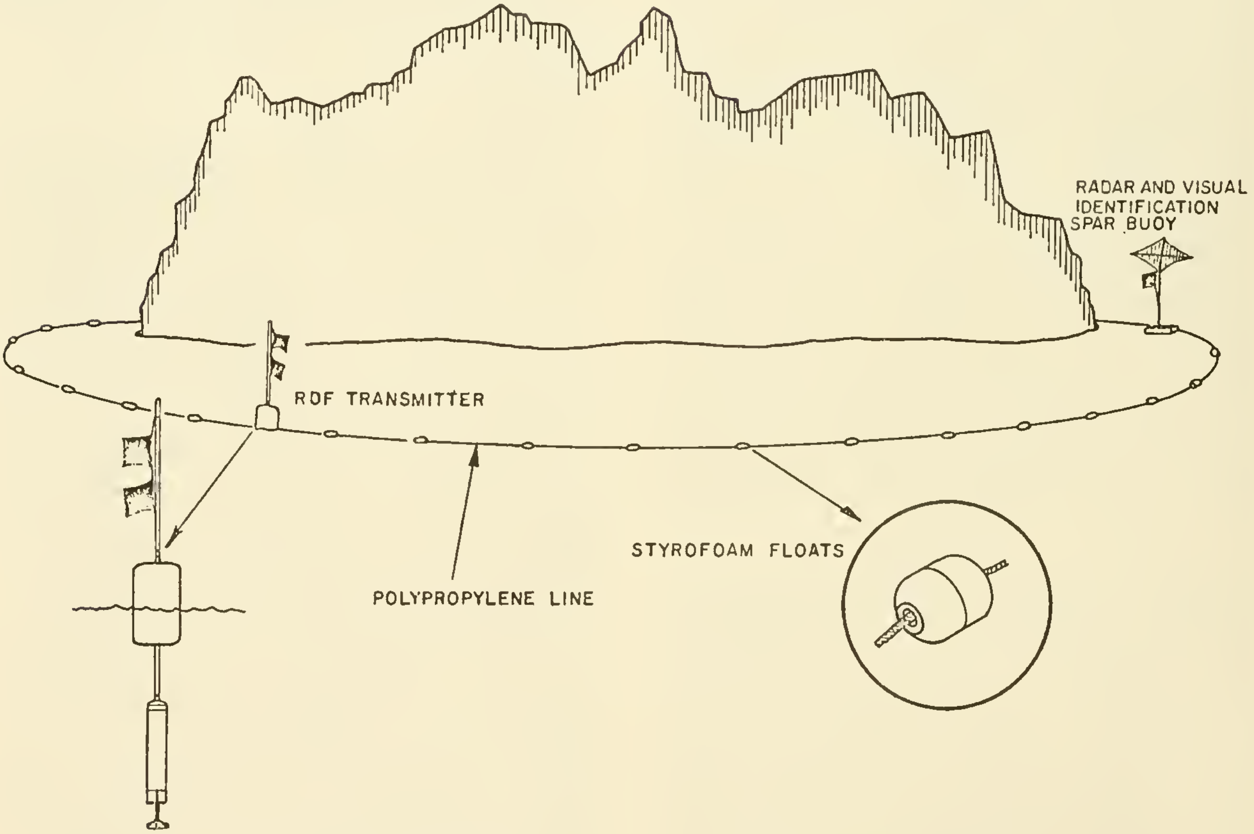

FIGURE A-1—ICEBERG TAGGING ARRAY DEPLOYED DURING IIP 1974

Table A-1.—Iceberg Drift Data from IIP-2-74 Cruise

Iceberg#	Type Size (meters)	# of OBS.	Date/Time (Local) Observed (June 1974) From	To	Vector Averaged Drift Speed (KTS.)	Vector Averaged Drift Direction (°T)	Vector Averaged Wind Speed (KTS.)	Vector Averaged Wind Direction Minus 180° (°T)	*Average Angle of the Drift to the Right of the Wind (°)	Ratio of the Average Drift Speed of the Average Wind Speed
					$\bar{x}$	x	$\bar{x}$	$\bar{x}$	$\bar{x}$ s.d.	$\bar{x}$ s.d.
1	Medium Pinnacle 24x122	-	20/0911	23/1007	0.2	020	13.9	035	-021 ± 065	.016 ± .006
2	Large Pinnacle 37x137	-	20/0935	26/0348	0.4	156	11.2	041	092 ± 081	.041 ± .033
3	**Medium Drydock 16x101	8	24/1342	28/2300	0.9	198	12.1	134	060 ± 048	.071 ± .031
4	Small Domed 6x30	4	24/1607	26/0841	0.6	182	12.2	108	086 ± 018	.055 ± .012
5	Small Tabular 18x61	4	24/1823	26/0800	0.3	181	12.4	105	086 ± 018	.079 ± .015
6	Very Large Double Pinnacle 53x265	6	26/1700	29/0138	1.1	212	13.5	139	078 ± 020	.085 ± .025
ALL		36							058 ± 064	.056 ± .034

*Negative values indicate a drift angle to the left of the wind
**Iceberg #3 calved into two pieces between 28/0100 and 28/0928 (local)

ICEBERG DRIFT RESULTS

The drift of the six icebergs was determined for the time between observations as often as possible during the period 20/0911 Local to 29/0138 Local June 1974. The icebergs were tracked from 1.6 to 4.8 days. Wind velocities were logged hourly by the CGC EVERGREEN's bridge watch. All icebergs tracked during the experiment were found in the area bounded by 44–30N to 47–30N and 47–00W to 48–30W. Air temperatures during the iceberg tagging project ranged from 3.9°C to 9.4°C with an average about 6.4°C. The surface sea water temperature for the same period ranged from 1.1°C to 10.6°C with an average about 3.9°C. The weather was predominantly overcast with fog and visibility typically less than 100 yards for the entire drift survey. The sea state was moderate to calm. The data from observations taken during the second Ice Patrol cruise of 1974 are summarized in Table A–1.

The vector averaged drift for the bergs varied from 0.2 kts for iceberg #1 to 1.1 kts for iceberg #6. The average drift speed to average wind speed ratio ranged from 0.16 to 0.85. An expendable surface current probe was deployed in the van of iceberg #6 which measured a surface current of 1.23 kts setting at 193°T. This compared to the iceberg drift of 1.1 kts at 212°T. The wind was 13.5 kts from 319°T.

The drift angle with respect to the wind direction had a large standard deviation which was ±18° to ±81°. Furthermore, a number of observations (14%) indicated drift angles to the left of the wind. Ettle (1974) had iceberg drift data from past Ice Patrol cruises that gave a range of standard deviations for drift angles of ±54° to ±104°.

DISCUSSION OF ICEBERG DRIFT

Iceberg drift studies have always been handicapped by a lack of precise navigation and current information. In this study, satellite navigation was used for the first time, but since tagging the iceberg was of primary interest few current measurements were taken. Budinger (1960) put together a drift experiment that used current measurements, but was plagued by the poor precision of the geomagnetic electro-kinetograph (GEK) surface current measurements and by inadequate navigation. Ettle (1974), in his analysis, did not treat the currents in the area of the drifting iceberg. Therefore, his results do not separate out the effect of the wind. In order

to obtain precise positions, some investigators placed marker buoys in shallow water and plotted positions relative to the buoy. This procedure had at least two drawbacks. The first was that the berg could only be tracked for a limited distance before the marker had to be moved. Second, using a buoy required that the drift study be conducted in shallow water where tidal currents and turbulence had a much greater impact than in the deeper ocean.

Now that satellite navigation is available, it is possible to plan a more precise and more sophisticated approach to iceberg drift.

The elements that contribute to the dirft of an iceberg are as follows:

a. The current system, composed of barotrophic and baroclinic components, is probably the most influential factor in iceberg drift.

b. The wind has two effects on iceberg drift. First, the drag on the iceberg itself by the wind. Second, the wind-included current which adds to and modifies whatever surface current already exists.

c. The Coriolis effect which arises from the rotation of the earth and acts to the right of the velocity of the iceberg in the Northern Hemisphere.

d. Finally there is a small force associated with the slope of the sea surface which tends to move the iceberg downhill.

An iceberg moving with a uniform velocity has no net force acting on it; all forces balance. When one of the forces change, the iceberg accelerates or decelerates until a new equilibrium of forces is obtained. The net force can be determined by the change of the drift vector over some time interval.

At the same time that the drift of the iceberg is measured, measurement of wind, calculation of the geostrophic current, and the surface current intergrated over the depth of the iceberg must be made. The force exerted by a fluid on an immersed body is a function of both the drag of the fluid on the body and of the square of the velocity of the object relative to the fluid. Since the iceberg is affected by both air and water, there are two drag terms. If these drag coefficients are determined from the experimental data, then for a given wind velocity, the velocity of the wind driven surface current and the velocity of the iceberg can be calculated by integrating the drag forces over a time period necessary to reach equilibrium.

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APPENDIX B

1974 LABRADOR COAST OCEANOGRAPHIC SURVEY

Smith (1937), using oceanographic station observations collected by the CGC MARION in 1928 and CGC GENERAL GREENE in 1933, has written the most definitive work concerning the characteristics of the Labrador Current over the Labrador continental shelf. In July of 1948, 1949, and 1962, the International Ice Patrol conducted limited oceanographic cruises into the Labrador Sea region without further studying Labrador Current properties. In the summer of 1965, an oceanographic survey was conducted from Cape Dyer, Baffin Island to South Wolf Island, Labrador neglecting the area from about Cape White Hankerchief, Labrador to South Wolf Island (Kollmeyer, 1967). During July and August of 1966, an extensive oceanographic study was done of the circulation of Hudson Strait and its contiguous areas. Again little oceanographic work was done along the coast of Labrador. In July 1968, a 48 station oceanographic survey consisting of four sections was conducted between Hamilton Inlet, Labrador and Belle Isle Strait (Andersen, 1971). Unfortunately three or four more sections were not placed between Hamilton Inlet and Cape White Handkerchief to tie together all of the oceanographic work done by the Ice Patrol in that area.

From 8–14 September 1974, an oceanographic survey was done over the Labrador continental shelf from Bears Gut fjord to South Wolf Island, Labrador (fig. 1). Since the CGC EDISTO (WAGB 284) was coming from Iceland, the Labrador Sea section was also occupied. This survey should definitively determine the relative velocity field in a previously neglected region. Results of this field work will appear in the Unit's Oceanographic Report Series (CG 373).

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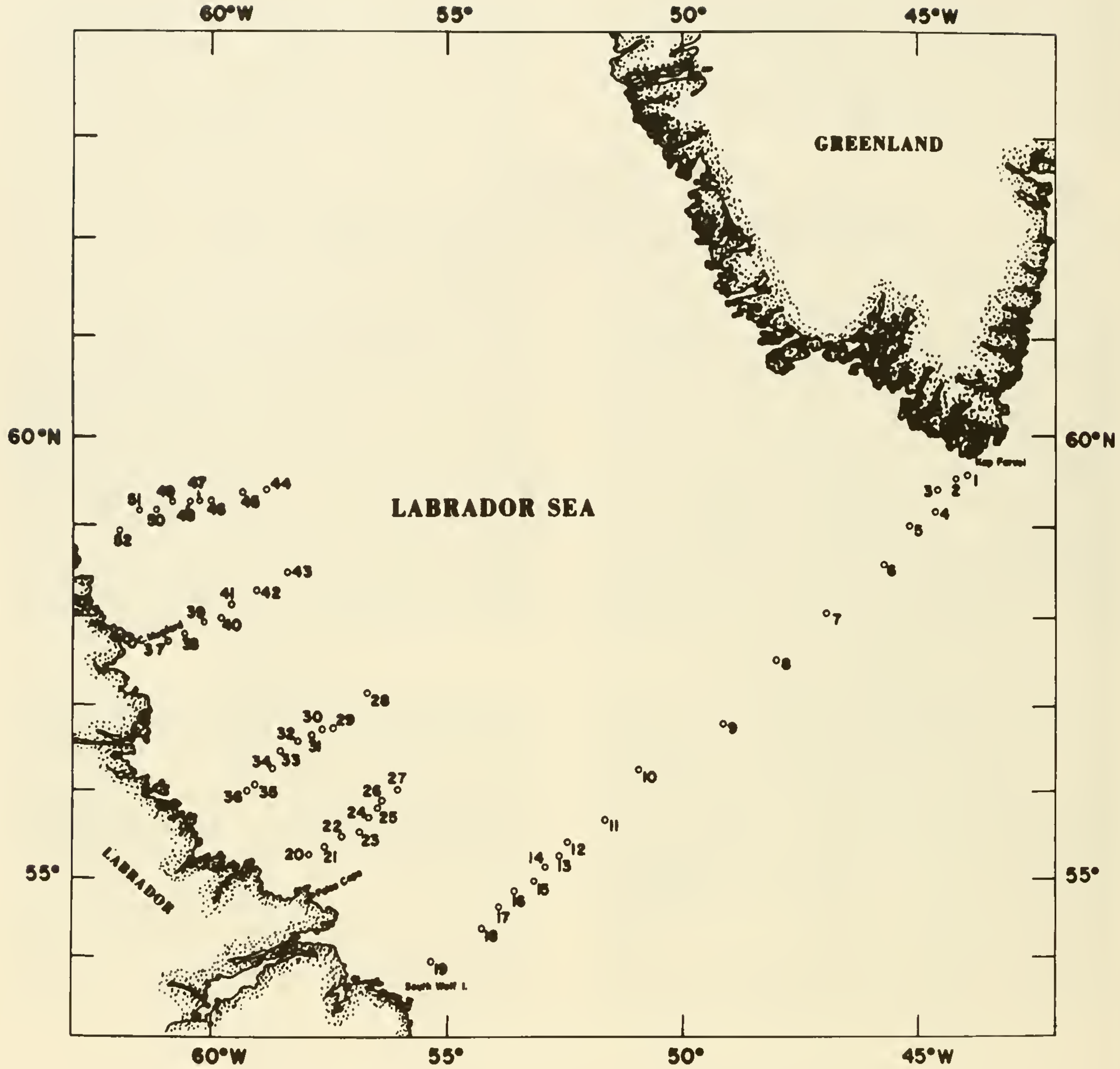

FIGURE 1.—Oceanographic stations occupied by CGC EDISTO 8–14 September 1974.

APPENDIX C

AN EVALUATION OF THE AIRBORNE RADIATION THERMOMETER FOR THE INTERNATIONAL ICE PATROL

by LTJG S. R. OSMER, USCG

Late in the 1974 Season, an airborne radiation thermometer (ART) was made available to Commander, International Ice Patrol, and was deployed for utilization and evaluation by the Ice Patrol Detachment. In 1954 the Ice Patrol conducted unsuccessful tests with an airborne radiation thermometer for the purpose of distinguishing between iceberg and non-iceberg radar targets under conditions of poor visibility. This device was called a bolometer. During the 1964 season, an airborne radiation thermometer was tested by the International Ice Patrol. While the actual water temperatures recorded by this instrument were not considered sufficiently reliable, the instrument was useful in detecting changes in surface water temperature, and therefore in locating the approximate position of the Labrador Current and its branches.

The main reason Commander, International Ice Patrol requested the ART was to, hopefully, improve the operational efficiency of the flights by determining sea surface temperature (SST) in the vicinity of icebergs to provide optimum deterioration data. Commander, International Ice Patrol , on a regular basis, "melts" icebergs. This "melt" is based upon conservative historical temperature deterioration data. The resulting survey could also map temperatures in the adjacent areas for continued iceberg melting as they drift.

Additionally, it was thought possible that the Labrador Current could be monitored on a continuous basis during routine flights. Although the Labrador Current is salinity driven, many of its features can be identified from themal measurements as can the northern wall and eddies of the North Atlantic Current. These determinations should then aid in predicting the direction of iceberg drift due to surface currents.

After a training period in June, the ART was flown on thirteen (13) ice reconnaissance flights in July. The normal altitude for such flights was 1000 feet. The data collected were then plotted and contoured. These isotherms were compared with the mean sea surface temperatures for July and the weekly SST charts produced by the Canadian Maritime Command (MARCOM). The MARCOM SST charts are used by the Ice Patrol Headquarters for the regular computing of iceberg life expectancy. These SST data are displayed in figures C–1 through C–7. All temperatures are in degrees Celsius (°C).

Four Ice Patrol flights were made during 7 to 10 July, four flights during 16 to 20 July, and five flights during 24 to 30 July. The flight tracks are shown on the ART charts. The gaps in data are due to the continuing problem International Ice Patrol faces each year on the Grand Banks—bad weather, in particular heavy fog, rain, and low-lying clouds. The ART is weather-limited in that the concentration of water vapor in the sampling column will cause a biased reading due to back radiation. Thus, if the surface to be observed is obscured by weather the ART cannot be used with any great weather reliability.

The ART SST for 7 to 10 July shows a very good agreement with the MARCOM Halifax 5 to 8 July SST. The 8° to 16° isotherms compare very well, while the 6° isotherm on the MARCOM chart tends to be further north and east than as shown on the ART chart.

For the next period, 16 to 20 July, the flights were characterized by large gaps in data collection due to weather. This can be inferred from the chart. The ART SST shows a fair comparison with the MARCOM SST for the 6° to 12° isotherms. The 4° isotherm on the MARCOM

chart seems to indicate a warmer condition than that which the ART found.

For the next period. 24 to 30 July, the ART SST and MARCOM SST for 25 to 28 July show a very good agreement for the 10° to 16° isotherms. The MARCOM chart reflects a warmer condition by the location of the 8° isotherm as compared with that of the ART.

Though the ART data gathered in 1974 were only during one month, they do illustrate a good comparison with the temperature information presently being used by the Ice Patrol for iceberg deterioration data. The ART has one immediate advantage in that it enables the user to possess near real-time data, whereas the MARCOM charts normally arrive two weeks after the time period for which they were drawn.

Another advantage of the ART, though perhaps not as obvious as that above, is the quality of the data. The MARCOM SST charts are primarily drawn from sea surface temperatures reported by vessels transiting the area. Often, these data are not of the accuracy desired due to vessel measurement procedures and infrequent transits, and large regions may lack any reported temperature. However, the isotherms are faired in to fit the available information as best as possible. With the ART there is a continuous recording of temperature along the entire flight track, excluding areas of weather, enabling more representative temperature charts to be developed for the areas covered.

Commander, International Ice Patrol intends to utilize the ART during the 1975 Ice Season for the collection of deterioration data, and hopefully for current monitoring.

I would like to thank MST1 Neil O. TIBAYAN for his invaluable assistance in preparing the SST charts.

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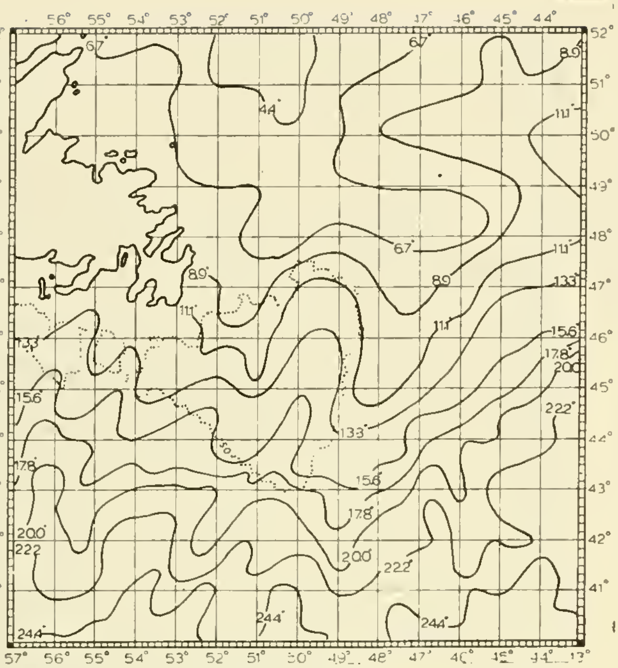

FIGURE C–1.—Mean Sea Surface Temperature for July.

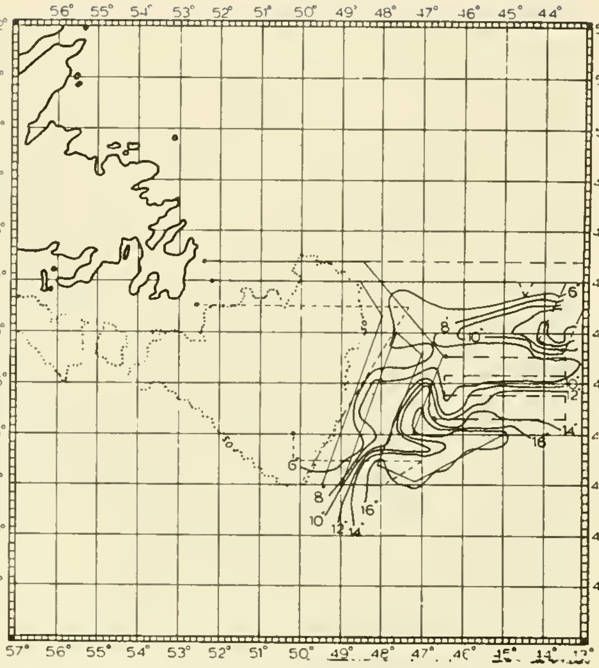

FIGURE C–2.—ART SST Flights, 7 to 10 July 1974.

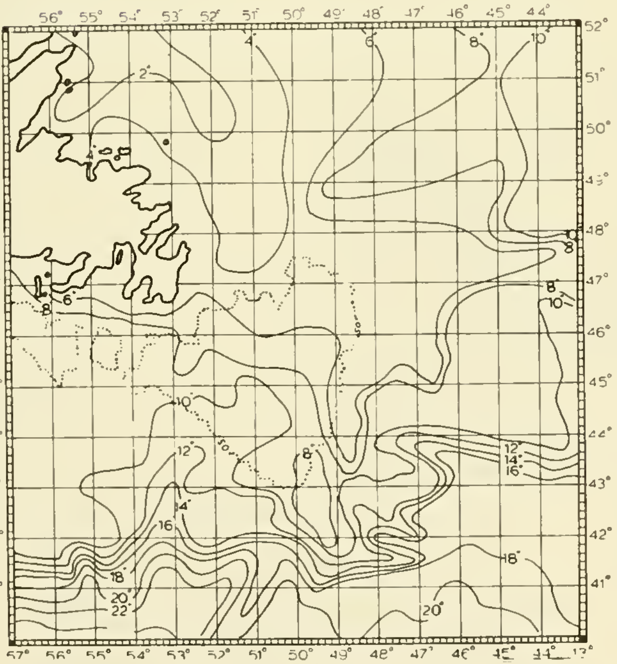

FIGURE C–3.—SST Marcom, Halifax, 5 to 8 July 1974.

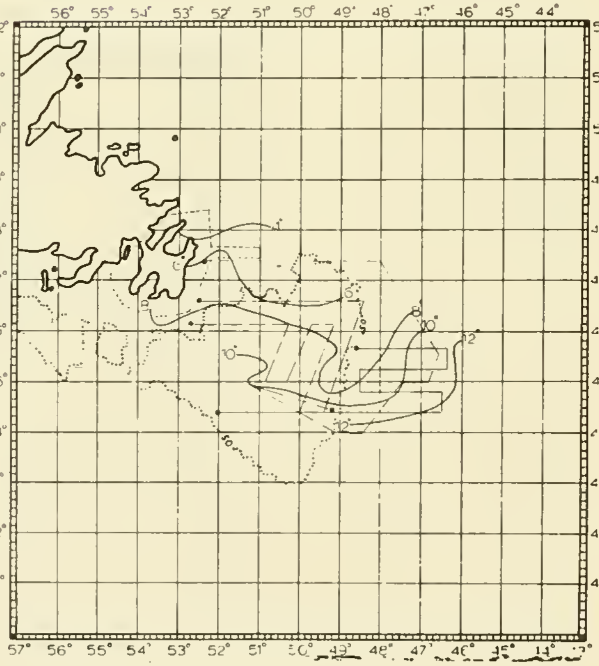

FIGURE C–4.—ART SST Flights, 16 to 20 July 1974.

Figure C–5.—SST Marcom, Halifax, 18 to 21 July 1974.

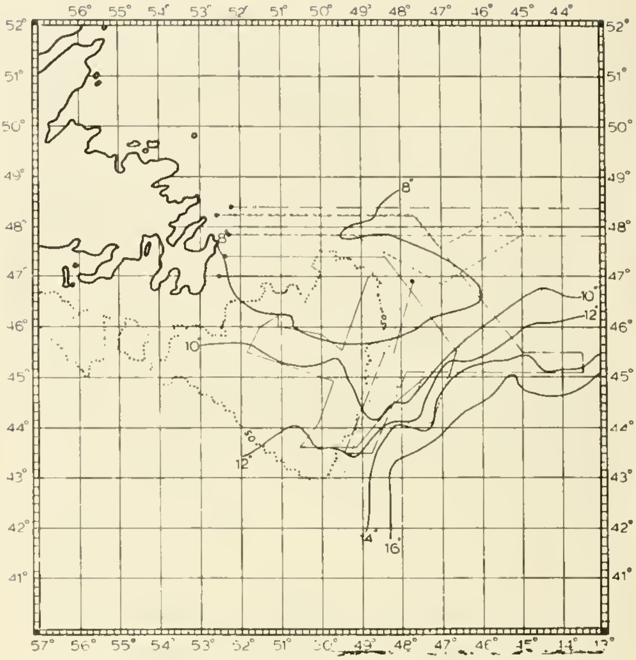

Figure C–6.—ART SST Flights, 24 to 30 July 1974.

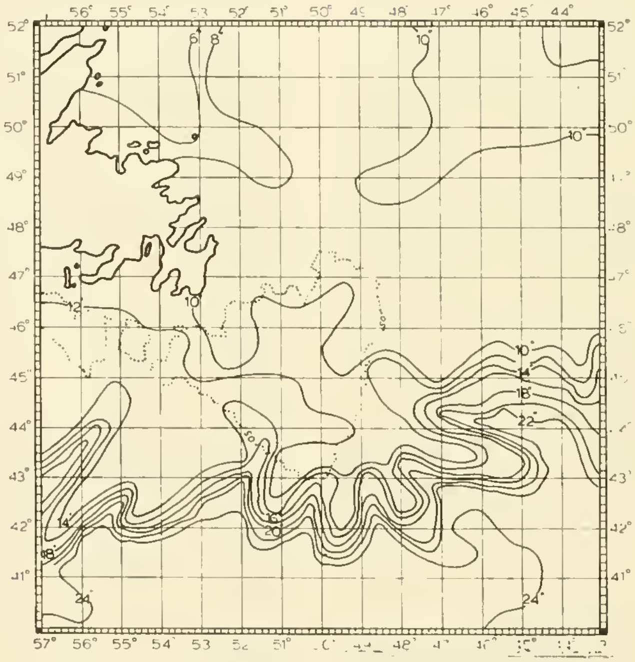

Figure C–7.—SST Marcom, Halifax, 25 to 28 July 1974.

APPENDIX D

ERTS–A EVALUATED

by LTJG S. R. OSMER, USCG

In October 1972, Commander, International Ice Patrol began receiving ERTS-A imagery covering the Grand Banks north to 60°N. This is the conclusion reached from two years of viewing this satellite imagery.

ERTS-A (Earth Resources Technology Satellite) was launched on 23 July 1972. The life expectancy was one year. Imagery was still being beamed to earth when ERTS-B was launched on 19 January 1975.

The ERTS mission was to gather high resolution multispectral data of the earth's surface on a global basis. The sensor payload contained two systems to accomplish this mission—a four channel Multispectral Scanner System (MSS) and a three camera Return Beam Vidicon (RBV) system.

The following descriptions are from the ERTS Data Users Handbook. ERTS-A operated in a circular sun synchronous, near-polar orbit at an altitude of 494 nautical miles. It circled the earth every 103 minutes, completing 14 orbits per day and viewed the entire earth every 18 days. The orbit was selected and kept trimmed so that the satellite ground trace repeated its earth coverage at the same local time every 18 day period within 20 nautical miles.

The RBV operated in the range of 0.48 to 0.83 micrometers visible wavelengths. Each camera sensed a diferent spectral band. However, due to its large power demand, this system was rarely used.

The MSS imagery was viewed by the Ice Patrol. The four bands of the MSS were:

Band 4 --------	0.5–0.6 micrometers
Band 5 --------	0.6–0.7 micrometers
Band 6 --------	0.7–0.8 micrometers
Band 7 --------	0.8–1.1 micrometers

All bands were in the visible spectrum for daylight operation. Bands 6 and 7 were near-infrared bands. Photographic products were received in two sizes—70mm and 9.5 inch positive transparencies. The respective scales were 1:3,369,000 and 1:1,000,000.

The MSS gathered data by imaging the surface of the earth in several spectral bands simultaneously through the same optical system. It scaned crosstrack swaths of 185 kilometers (100-nm) square width.

The MSS precision output product had a residual error for positional mapping accuracy of 242 meters.

The July 1972 issue of *Aviation Week and Space Technology* stated the operating resolution of the MSS was expected to be about 225 feet. The September 1973 issue of *Environmental Data Service* stated ERTS was capable of resolution approaching 100 meters (about 330 feet).

Thomas Ragland, Assistant Project Manager ERTS/NIMBUS, NASA/GSFC, in correspondence with International Ice Patrol Headquarters in July 1972, stated that MSS Bands 5 and 6 were best for sighting icebergs. Under cloud free conditions, because of the good contrast between the ice and water in these bands, icebergs with exposed areas down to about 0.02 square kilometer (0.01 square miles) could expect to be seen.

Barnes (1973) stated that ice features as small as small floes (20 to 100m) across could be detected. He also stated that the MSS–4 and MSS–5 bands appeared to be best for mapping ice boundaries, whereas the MSS–7 band provided greater detail in the ice features. After a limited examination of color products, he felt there was no significant advantage in the use of color data for ice mapping. The size of features somewhat smaller than 100m across could be measured from enlarged ERTS prints. Most im-

portant, Barnes (1973) stated that although larger icebergs could be seen, it was difficult to distinguish them from ice floes.

Late November 1972, Commander, International Ice Patrol submitted with Dr. Albert Rango, Hydrologist of the Earth Survey Sciences Office, a research proposal to NASA for analysis of data from ERTS-B. Dr. Rango's investigation (1973) dealt with the satellite capabilities for locating Arctic icebergs for possible use in supplementing fresh water supplies in coast areas. Naturally, Commander, International Ice Patrol was interested in utilizing the satellite to locate, identify, and categorize the icebergs as to size in an attempt to predict the severity of the ice seasons, follow the drift of the bergs, and monitor them while they were present on the Grand Banks. This imagery was only expected to supplement, not replace, current ice reconnaissance methods.

In his proposal Rango (1973) stated that MSS bands 5 and 7 would be most useful in detecting differences that might have been relatively subtle. Band 5 would show the best contrast between ice and water, and Band 7 would distinguish between solid ice and ice with melt water on the surface or mixtures of ice and water. The report envisioned classifying icebergs greater than 100 meters in length (or surface areas greater than .01km^2). The following table appeared in the proposal, and summarizes what the investigators expected to be able to see with ERTS-B.

Table 1.—Description of icebergs according to length and type

Size (except tabular type)	*Length (meters)*
Growler* –	<6
Bergy Bit*	6—15
Small Iceberg**	15—61
Medium Iceberg	61—122
Large Iceberg	122—213
Very Large Iceberg	>213
Size of tabular type	
Small**	<91
Medium	91—213
Large	>213

* will not be observable from ERTS-B
** will probably not be observable from ERTS-B

In July 1974, Dr. Rango's proposal was not accepted by NASA.

ERTS-A was not designed for oceanographic use, but primarily for earth surface applications. This has tended to limit the quantity and quality of significant results within the oceanographic discipline. ERTS-A is best suited for land and near coastal utilization.

Ice Patrol received third generation photographic products. The generation number assigned to photographic products is referenced to the initial output from the video tapes. This output is first generation, each successive photographic product generated adds one generation. Some resolution is lost with each generation.

For the time frame 15 January 1973 to 31 August 1973 in the area bounded by 40°N, 52°N, 40°W, and 57°W, there are 420 ERTS scenes. Likewise, for 1 March 1974 to 15 August 1974, for the same area, there are 478 scenes. The imagery was viewed, with the attempt of locating icebergs, not sea ice, and comparing with known berg locations. All four bands were viewed in many of the scenes. Band 7 seemed to provide the best contrast between the water and an object.

No icebergs were observed. Some of the ice floes may have been icebergs, but without ground truth to verify, there was no way of stating such with any certainty.

One glaring fact which emerged during the imagery viewing was the number of scenes practically useless due to cloud cover. Thus, the Ice Patrol problem of weather affects another remote sensing venture. The following is a breakdown of the cloud cover on the imagery:

	Total percent of scenes	
Percent of Cloud Cover	*1973*	*1974*
100	25	29
90 or more	39	51
80 or more	48	60
70 or more	55	68
60 or more	60	74
50 or more	65	78

The vast majority of the scenes viewed were those with less than 50% cloud coverage.

ERTS-A imagery has limited International Ice Patrol application due to:

(1) *Resolution*—advertised resolution of about 100m is not fine enough to identify an iceberg that would normally reach the Ice Patrol area. Icebergs possessing surface areas greater than $400m^2$ constitute 65% of the total iceberg population. Icebergs with surface areas of $1000m^2$ comprise less than 25% of the population. The $0.01km^2$ resolution of the ERTS-A provides identification of less than 1% of the icebergs of interest to the Ice Patrol.

(2) *Cloud cover*—the cloud/fog blanket normally present on the Grand Banks during several months of the Ice Season does not allow penetration by ERTS-A sensors. ERTS-B carries the same instrument package as ERTS-A. ERTS-C, tentatively scheduled for launch in CY–78, will have a MSS band 5 which will be in the near-infrared range.

(3) *Frequency of area coverage*—the same area is covered every 18 days, though at a latitude of of 40° image overlap is approximately 34.1%, 50° is 44.8%, and 60° is 57%. (Data Users Handbook) The frequency of coverage does not allow for the continuous monitoring of icebergs and their drift—a requirement for Ice Patrol utilization.

(4) User availability—Wiesnet (et al, 1974) states ERTS-A data is not suitable for immediate forecasting due to the great time lag in the user receiving the information. There is usually a 3 week delay from the time GSFC receives the imagery till the user receives it. Ice Patrol found this to be the case also.

Though ERTS holds no present promise for iceberg detection and tracking, Commander, International Ice Patrol is closely following satellite development and application for possible future utilization.

Other satellite imagery has been reviewed in the past by Ice Patrol, among these are the ESSA series, NIMBUS series, NOAA series, and the SMS/GEOS satellite. All are meteorological satellites with 1km resolution. The Ice Patrol utilizes the meteorological satellites for weather information for flight planning and for the sea ice edge. The GEOS satellite also has the capability for taking radiance temperature measurement. (VAETH, 1972) Though this has not at present been utilized by the Ice Patrol, future planning has this under consideration.

In CY 1978, NASA intends to launch SEASAT-A (Sea Satellite). The objectives of SEASAT are to demonstrate a capability to measure global ocean dynamics and physical characteristics, provide data for user applications, and to provide these data real-time to users. The Coast Guard is closely following this project. SEASAT potentially offers—(1) 36-hour repeat coverage globally; (2) data dissemination in near real-time (less than three hours delay advertised); (3) one of the sensors, the Synthetic Aperature Coherent Imaging Radar, will provide all-weather images with resolution approaching 25 meters; (4) another of its four senor systems, the Compressed Pulse Precision Radar Altimeter, will determine the topography of the sea surface which in turn will be related to current determinations. (SEASAT-A Program Plan and Definition)

Hopefully, SEASAT-A's promised potential will find utilization by the International Ice Patrol.

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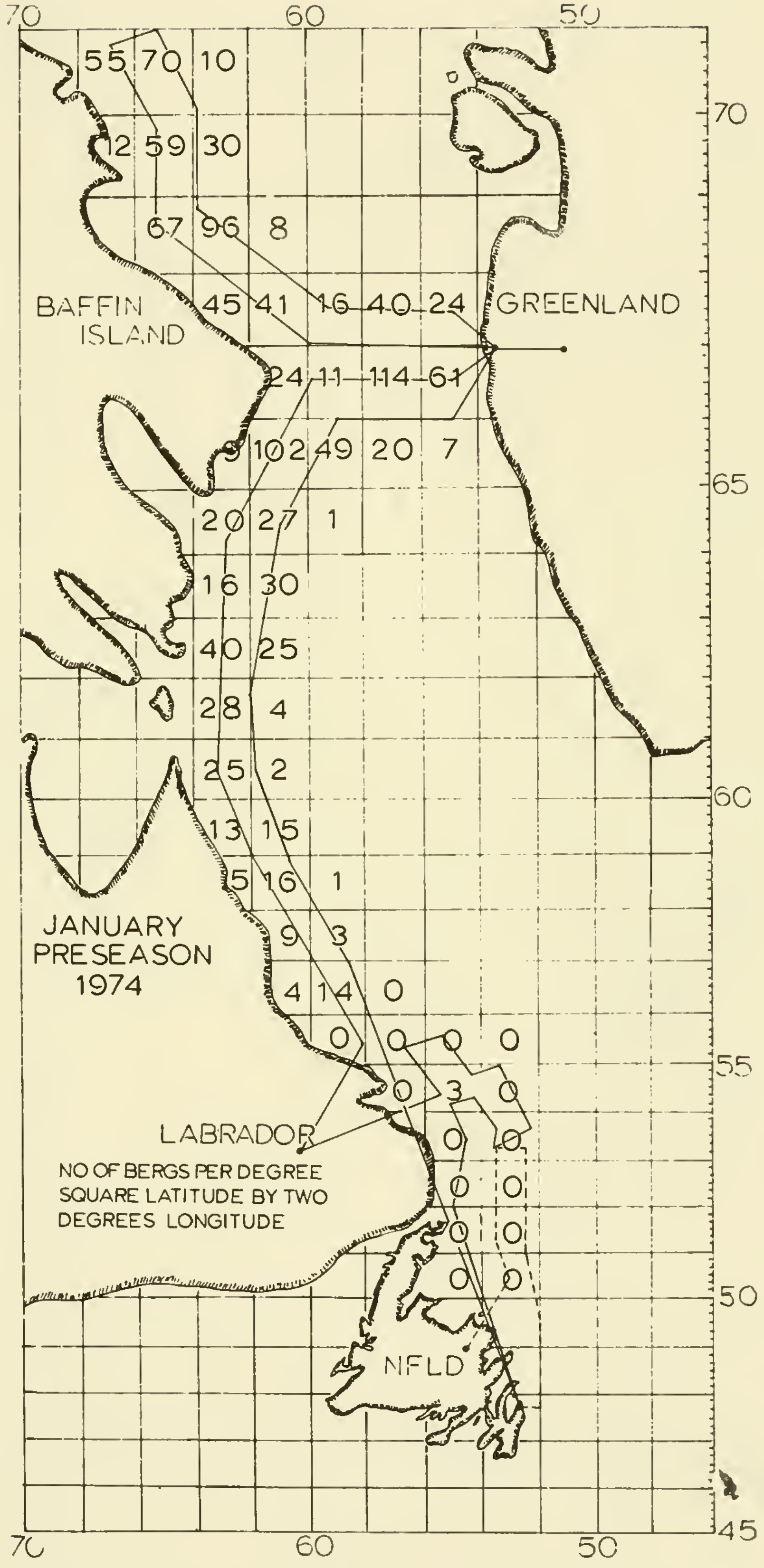

FIGURE 1.—Preseason Iceberg Survey 6–15 January 1974

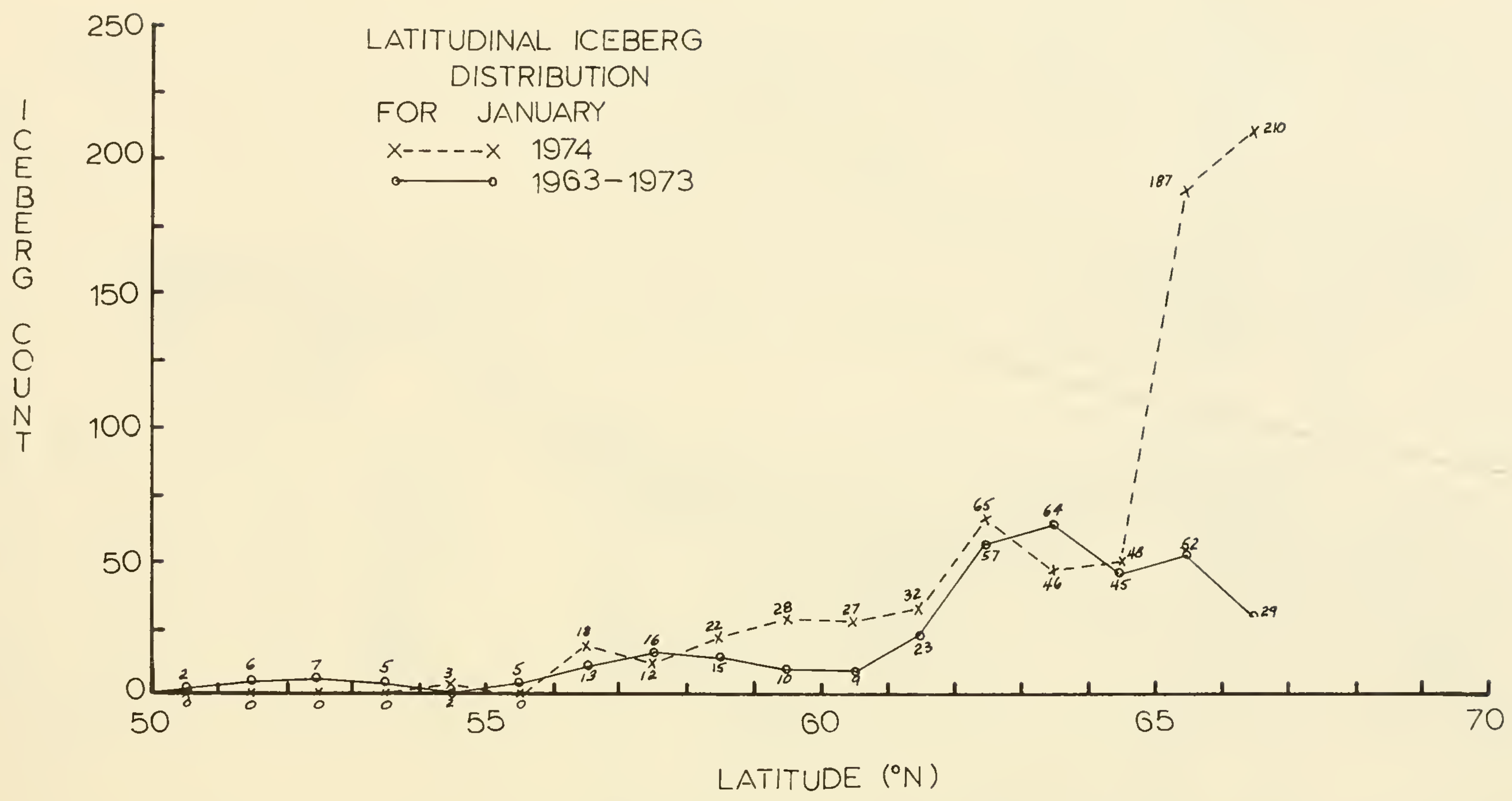

FIGURE 2.—Latitudinal Iceberg Distribution, January Preseason Flights.

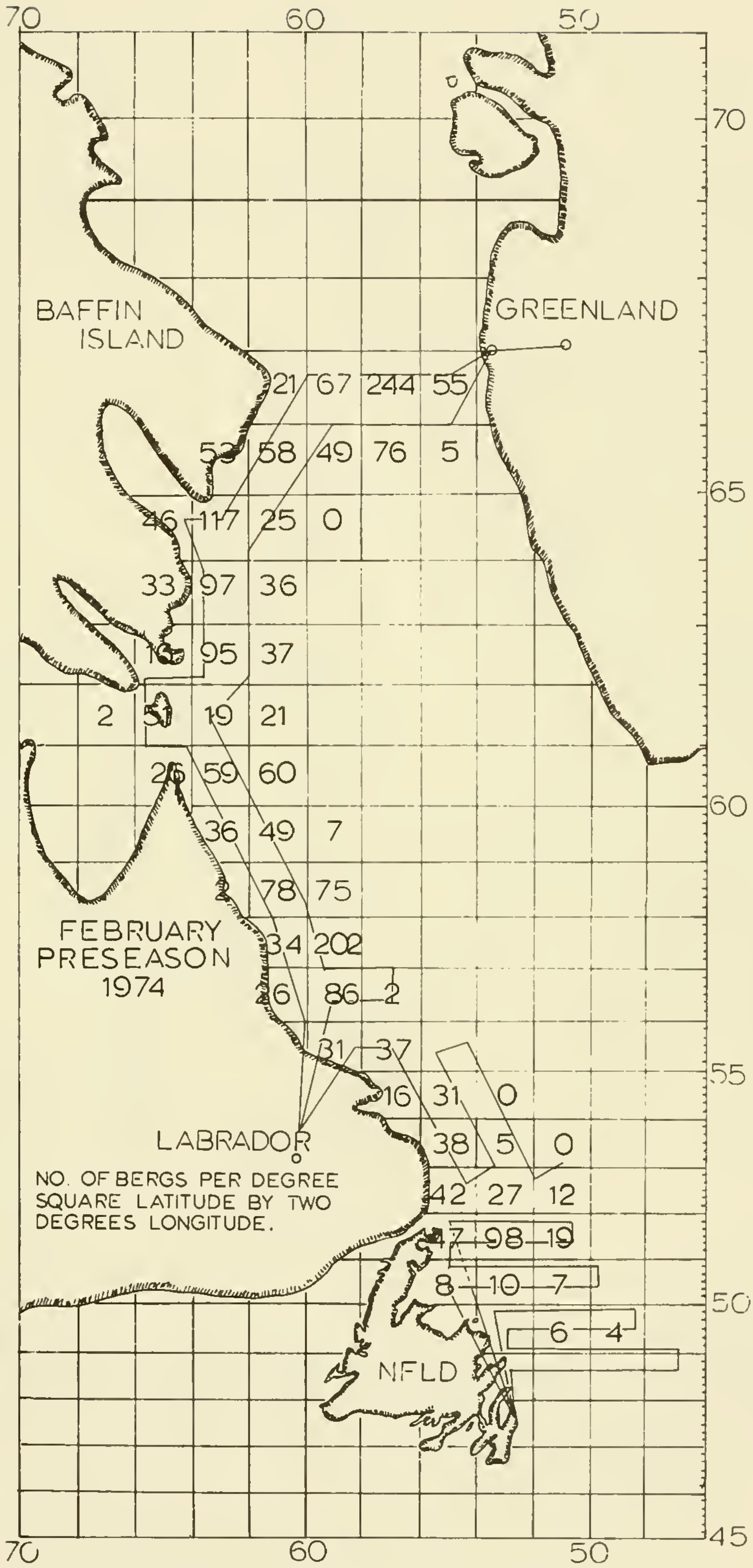

FIGURE 3.—Preseason Iceberg Survey 19 February—1 March 1974.

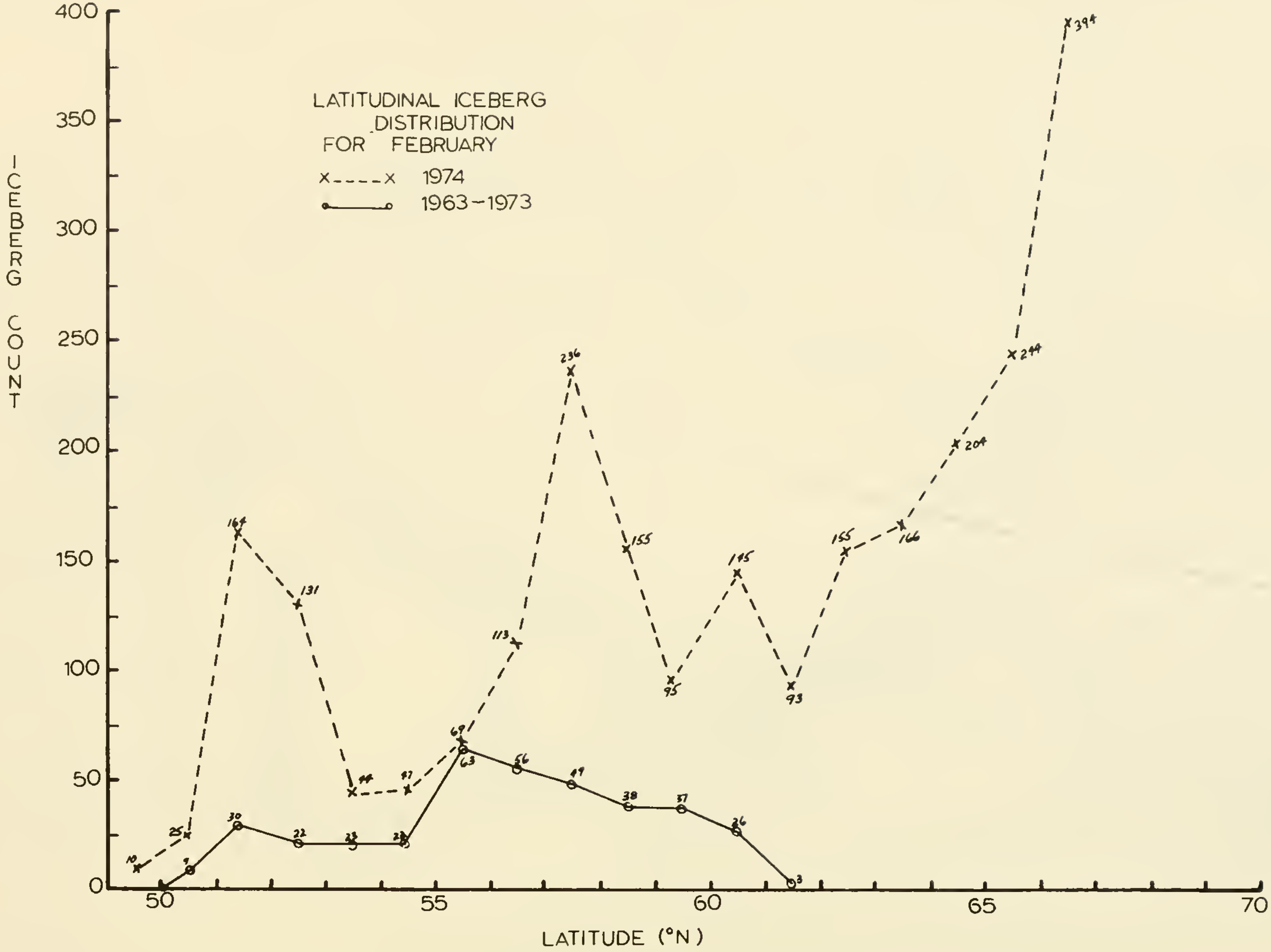

FIGURE 4.—Latitudinal Iceberg Distribution, February Preseaon Flights.

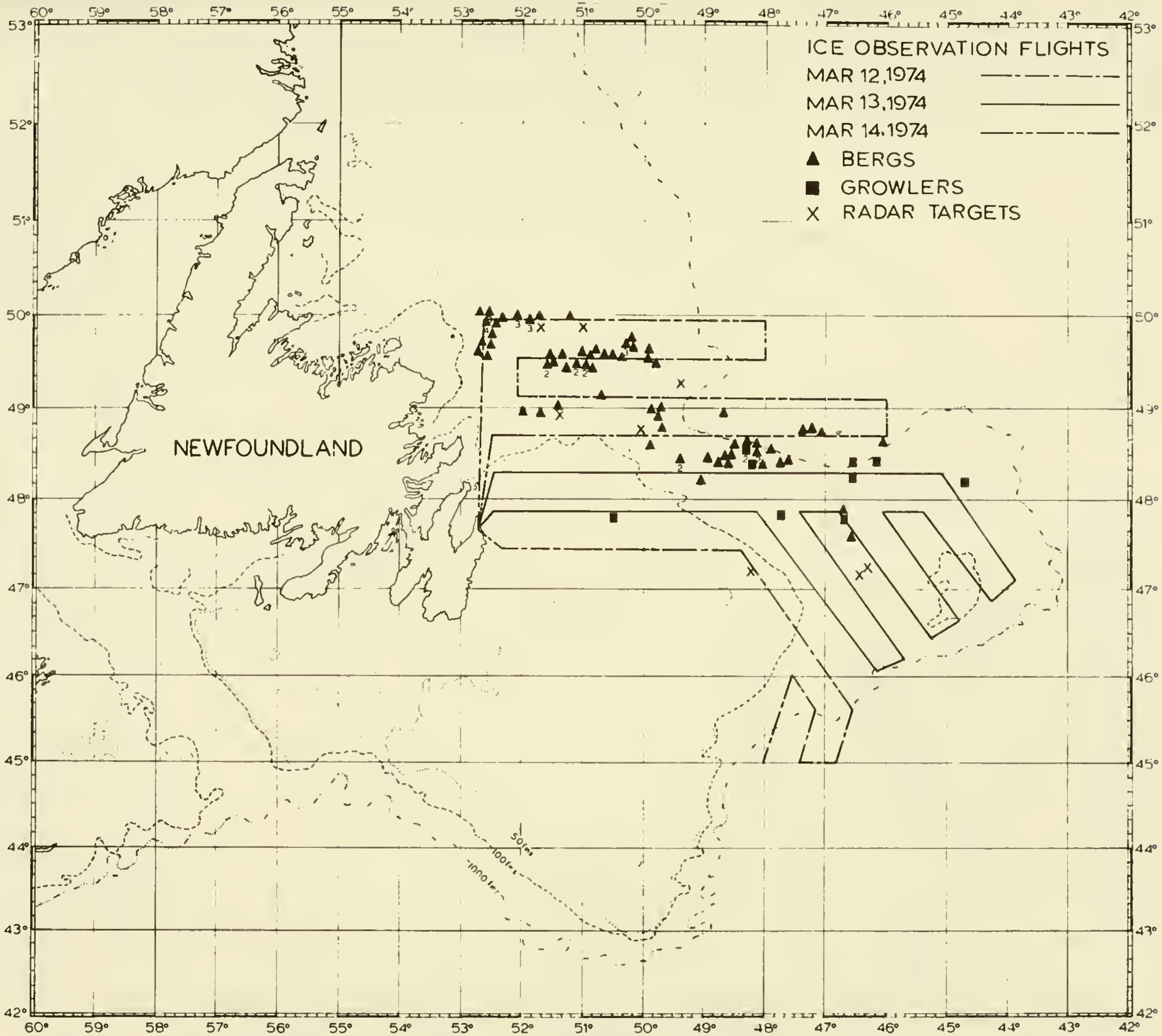

FIGURE 5.—12, 13 & 14 March 74 Preseason Flight Tracks and Iceberg Distribution.

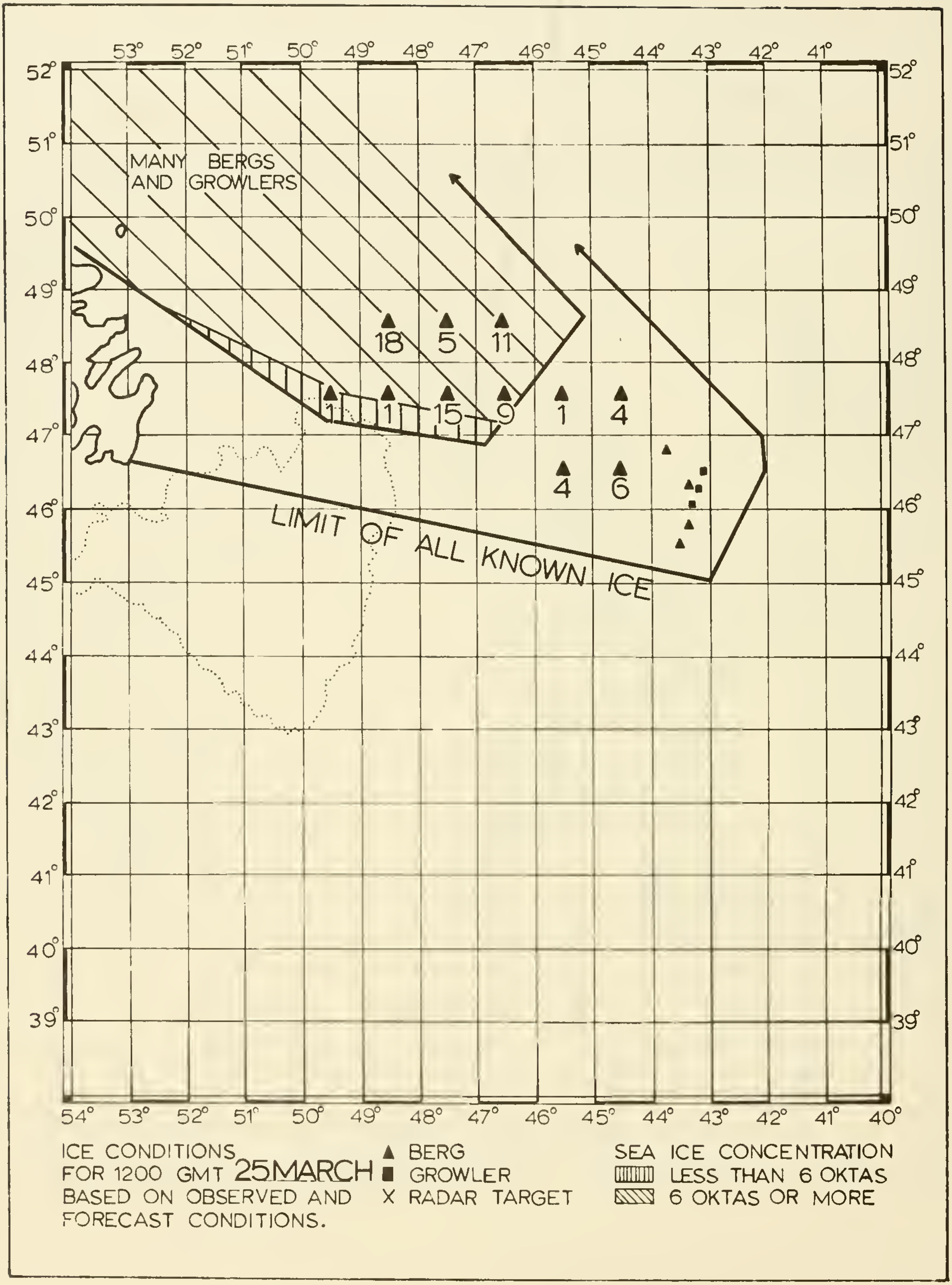

FIGURE 6.—Ice Conditions, 1200 GMT 25 March 1974.

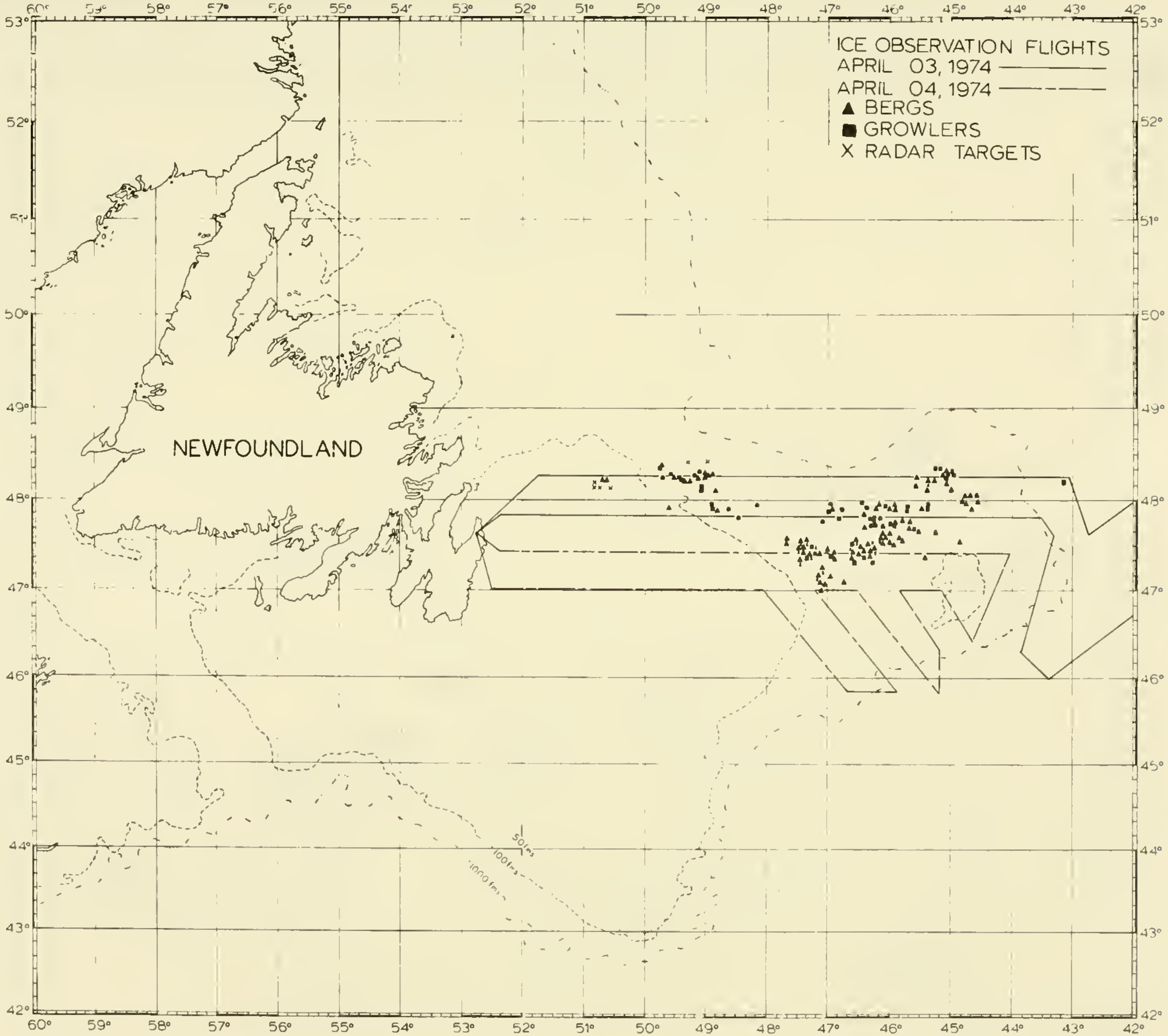

FIGURE 7.—Ice Reconnaissance Flights, 3 and 4 April 1974.

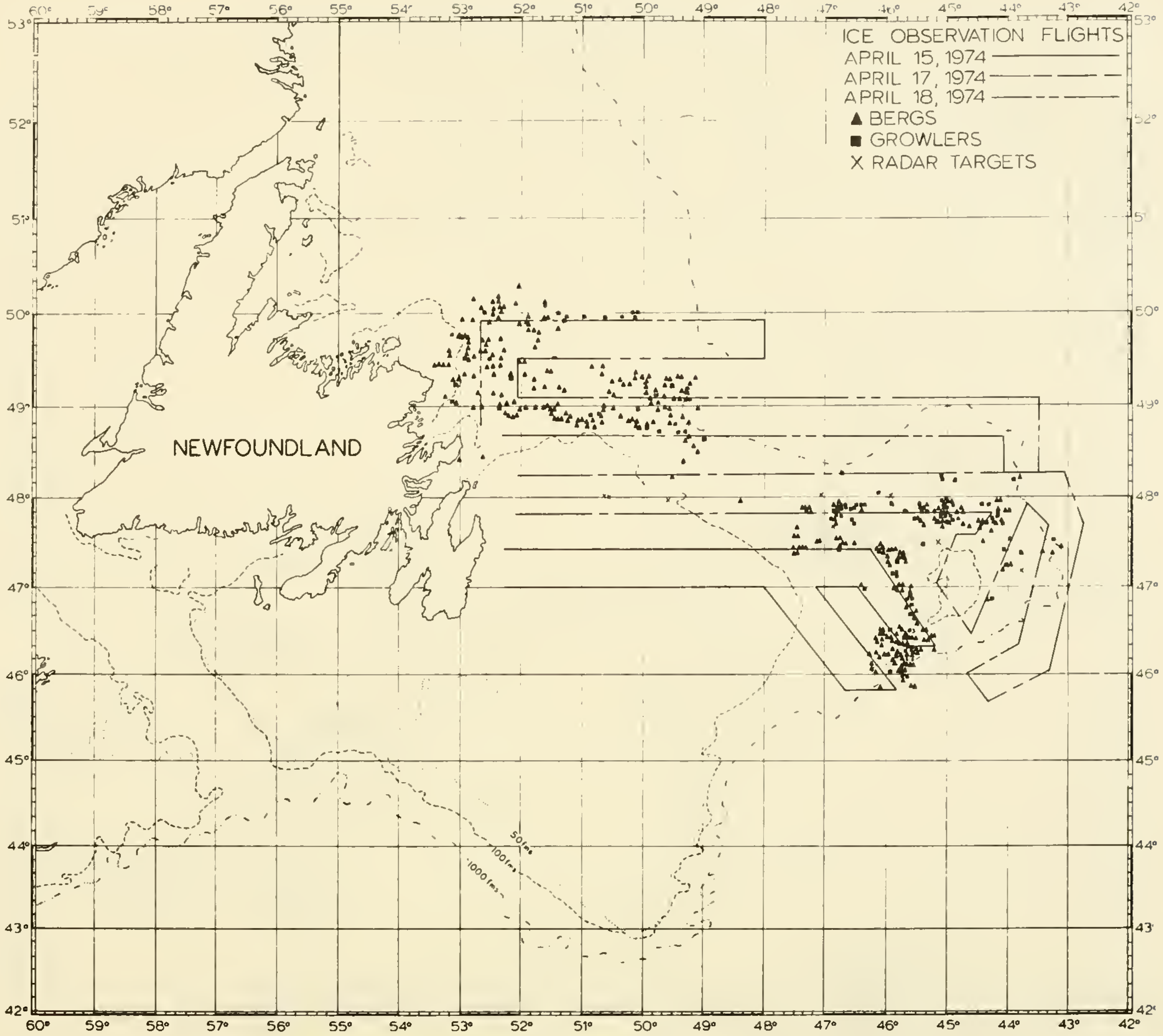

FIGURE 8.—Ice Reconnaissance Flights, 15, 17 and 18 April 1974.

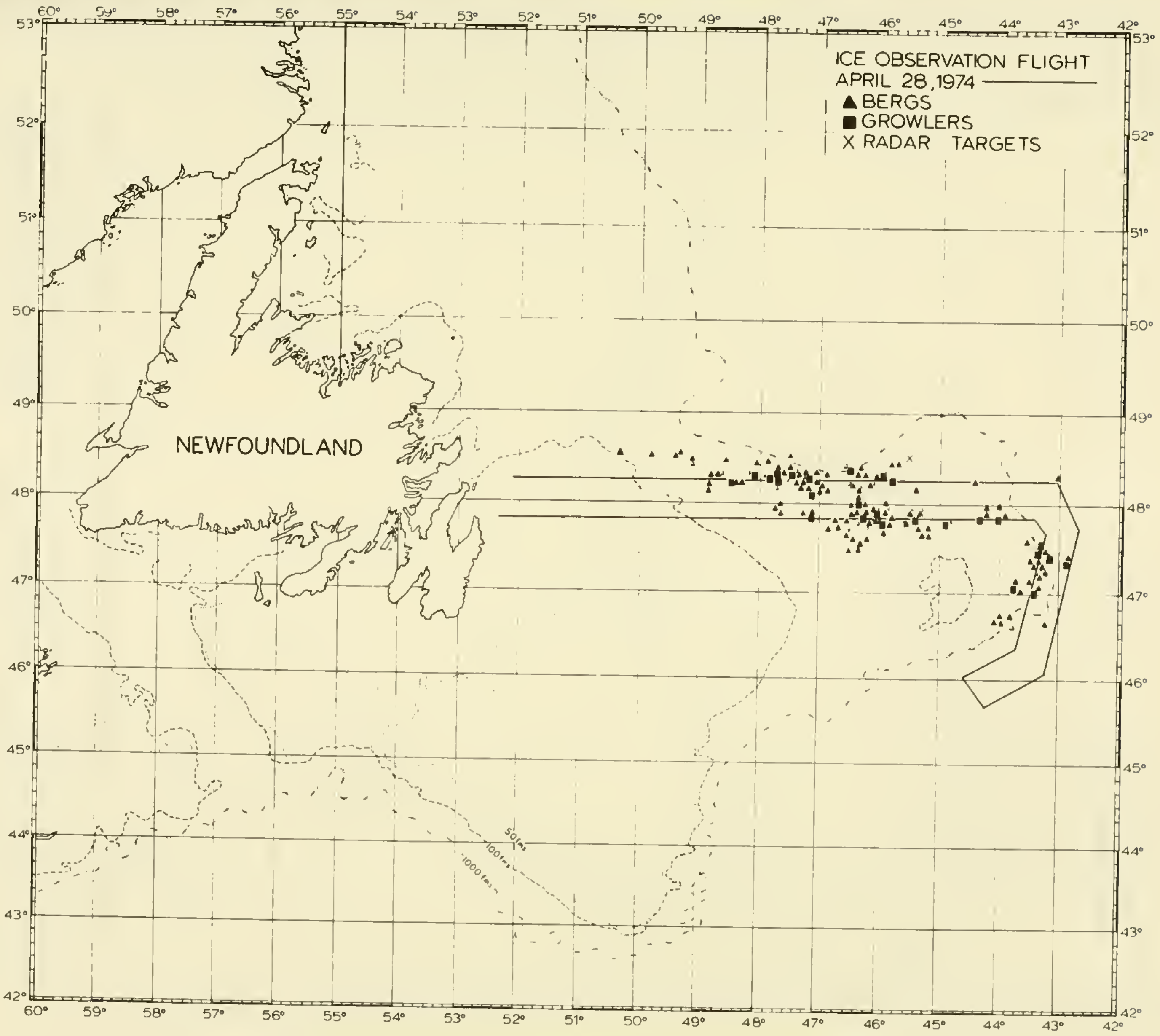

FIGURE 9.—Ice Reconnaissance Flight, 28 April 1974.

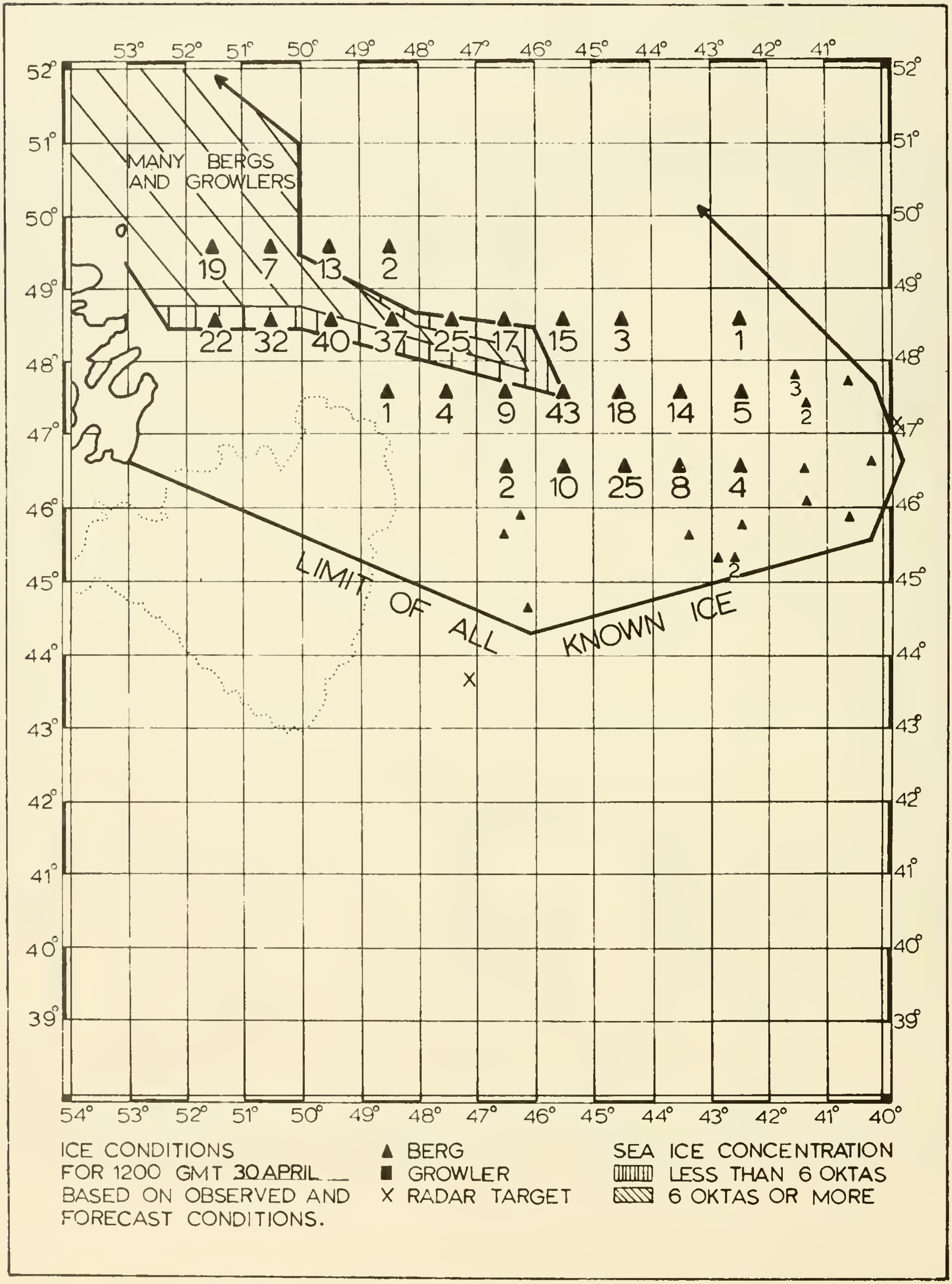

FIGURE 10.—Ice Conditions, 1200 GMT 30 April 1974.

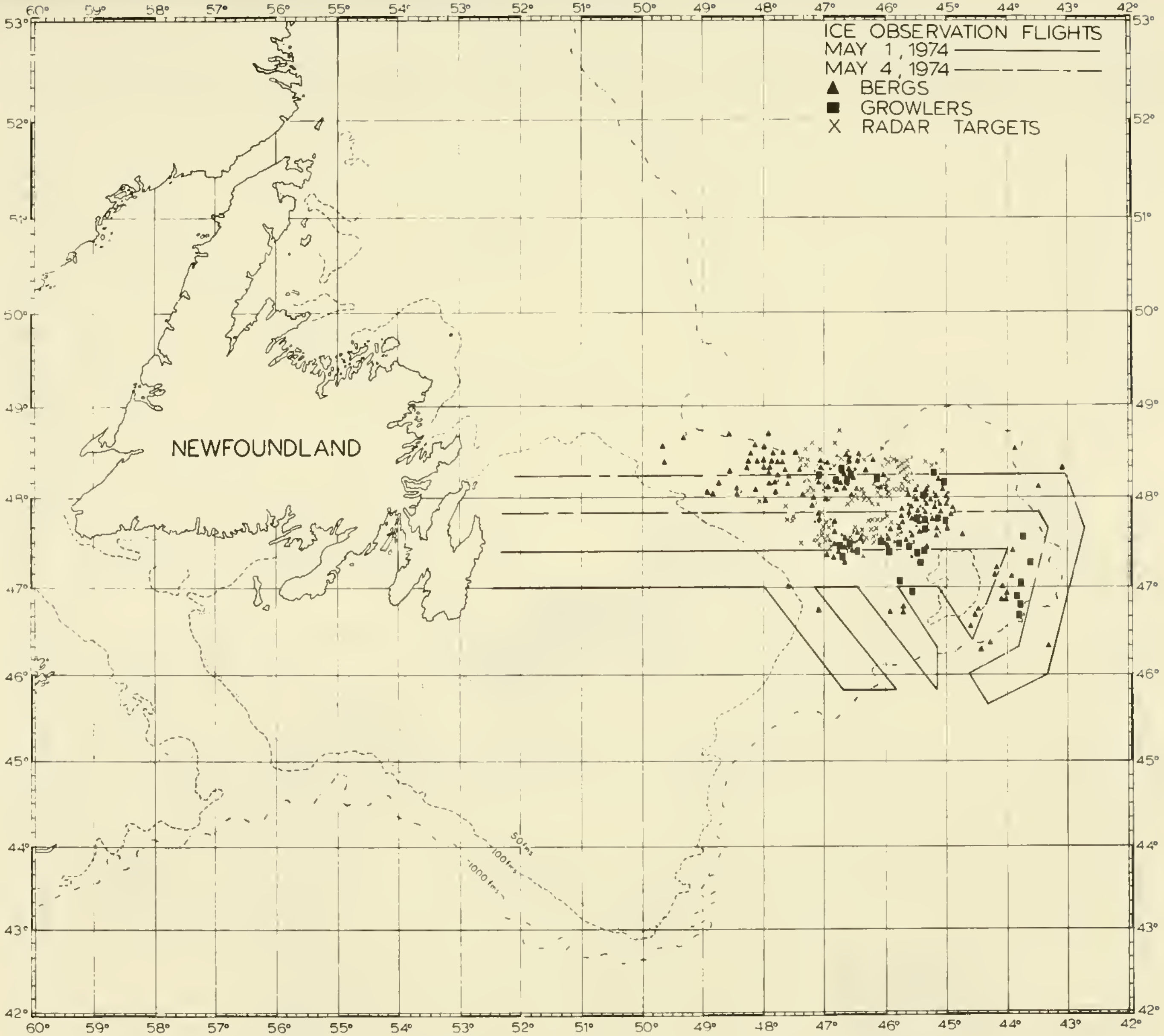

FIGURE 11.—Ice Reconnaissance Flights, 1 and 4 May 1974.

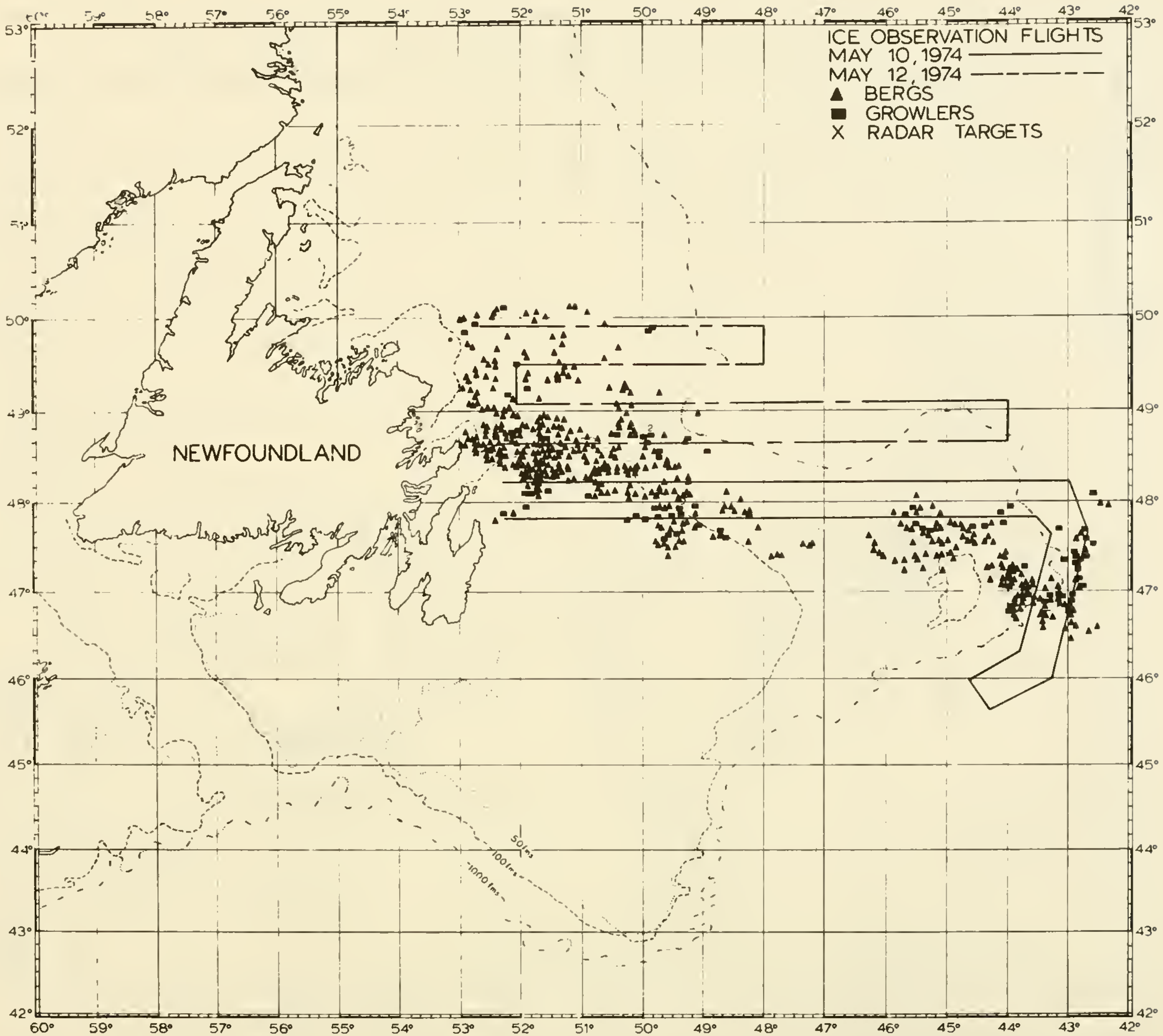

FIGURE 12.—Ice Reconnaissance Flights, 10 and 12 May 1974.

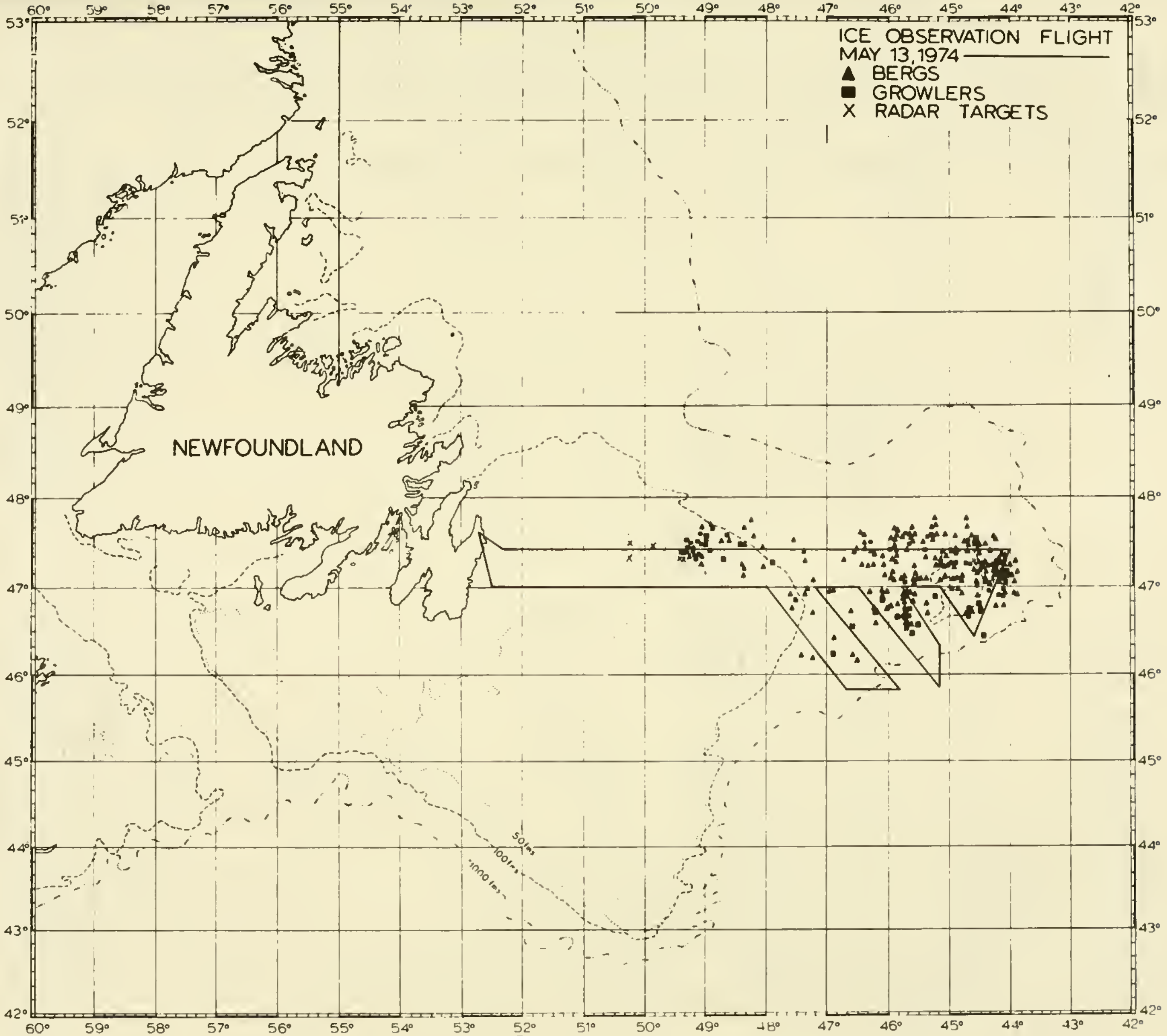

FIGURE 13.—Ice Reconnaissance Flight, 13 May 1974.

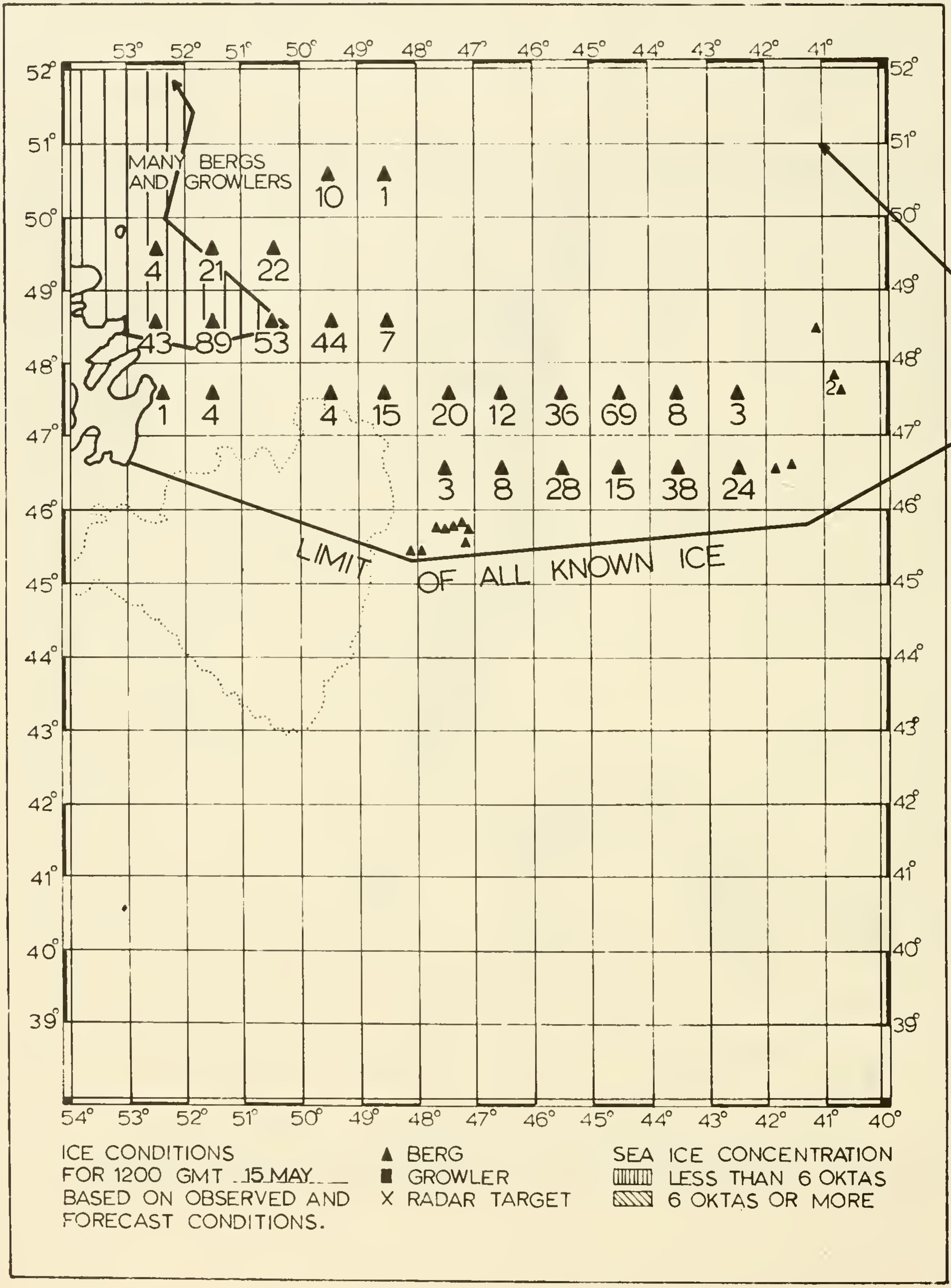

FIGURE 14.—Ice Conditions, 1200 GMT 15 May 1974.

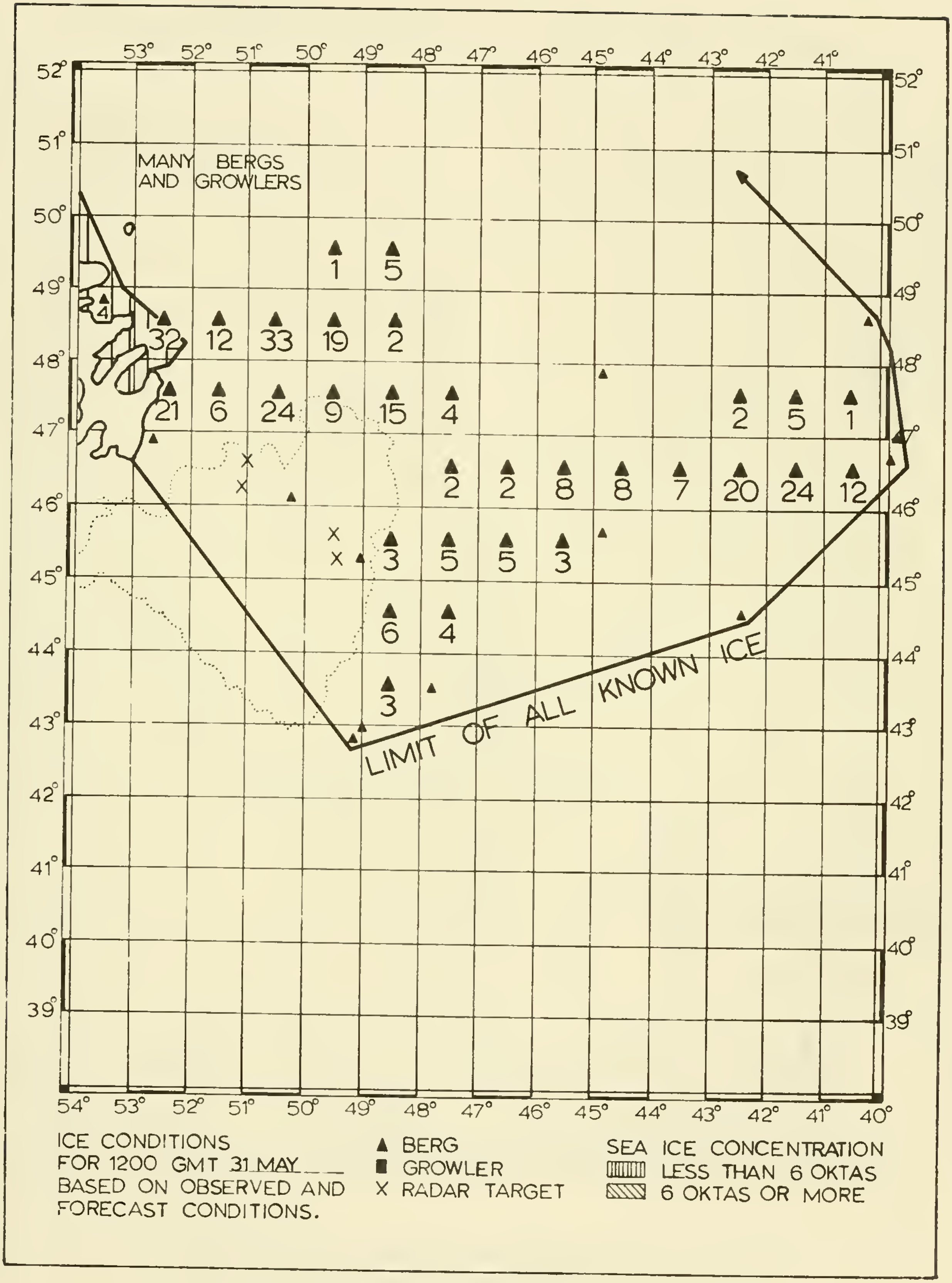

FIGURE 15.—Ice Conditions. 1200 GMT 31 May 1974.

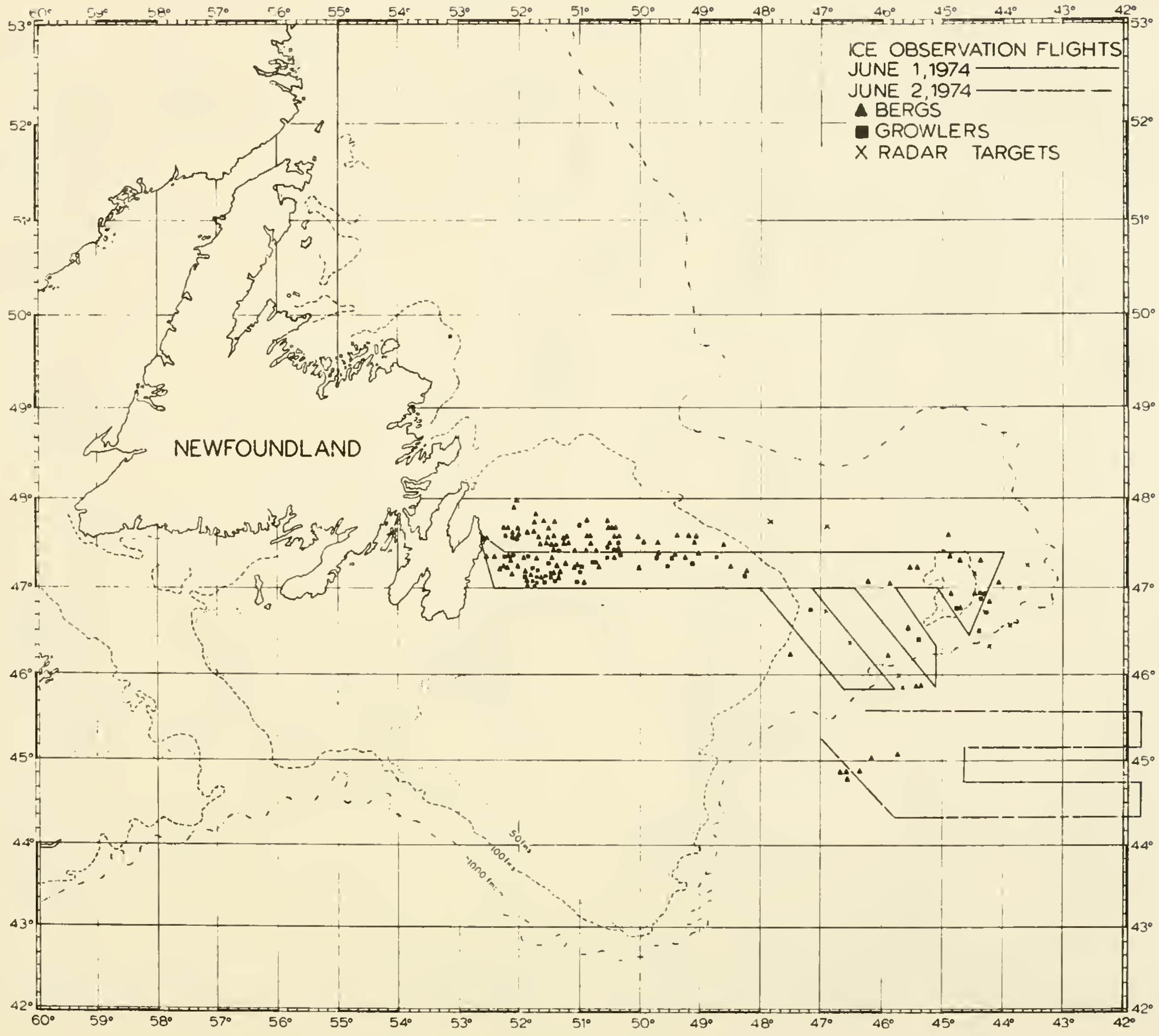

Figure 16.—Ice Reconnaissance Flights, 1 and 2 June 1974.

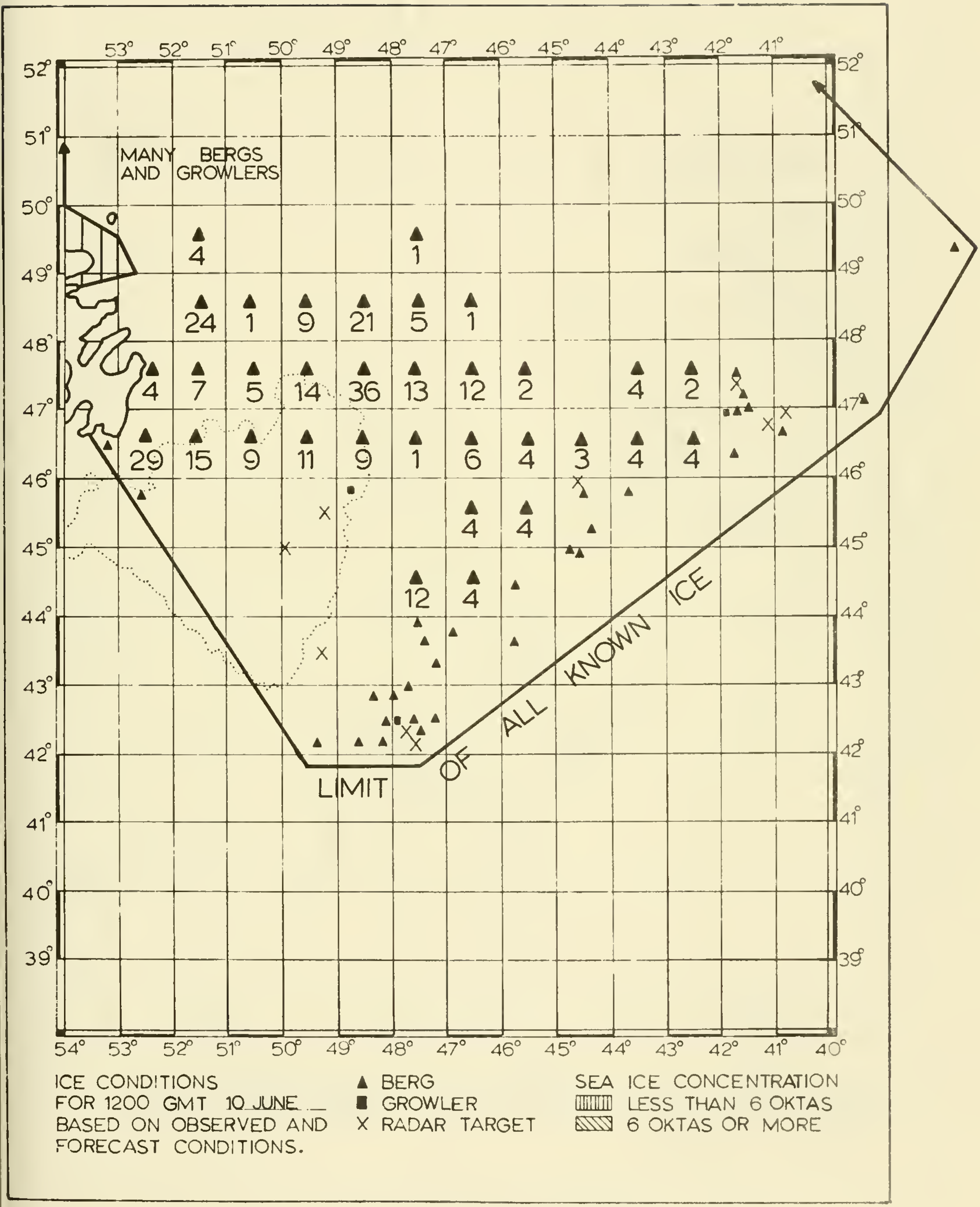

FIGURE 17.—Ice Conditions, 1200 GMT 10 June 1974.

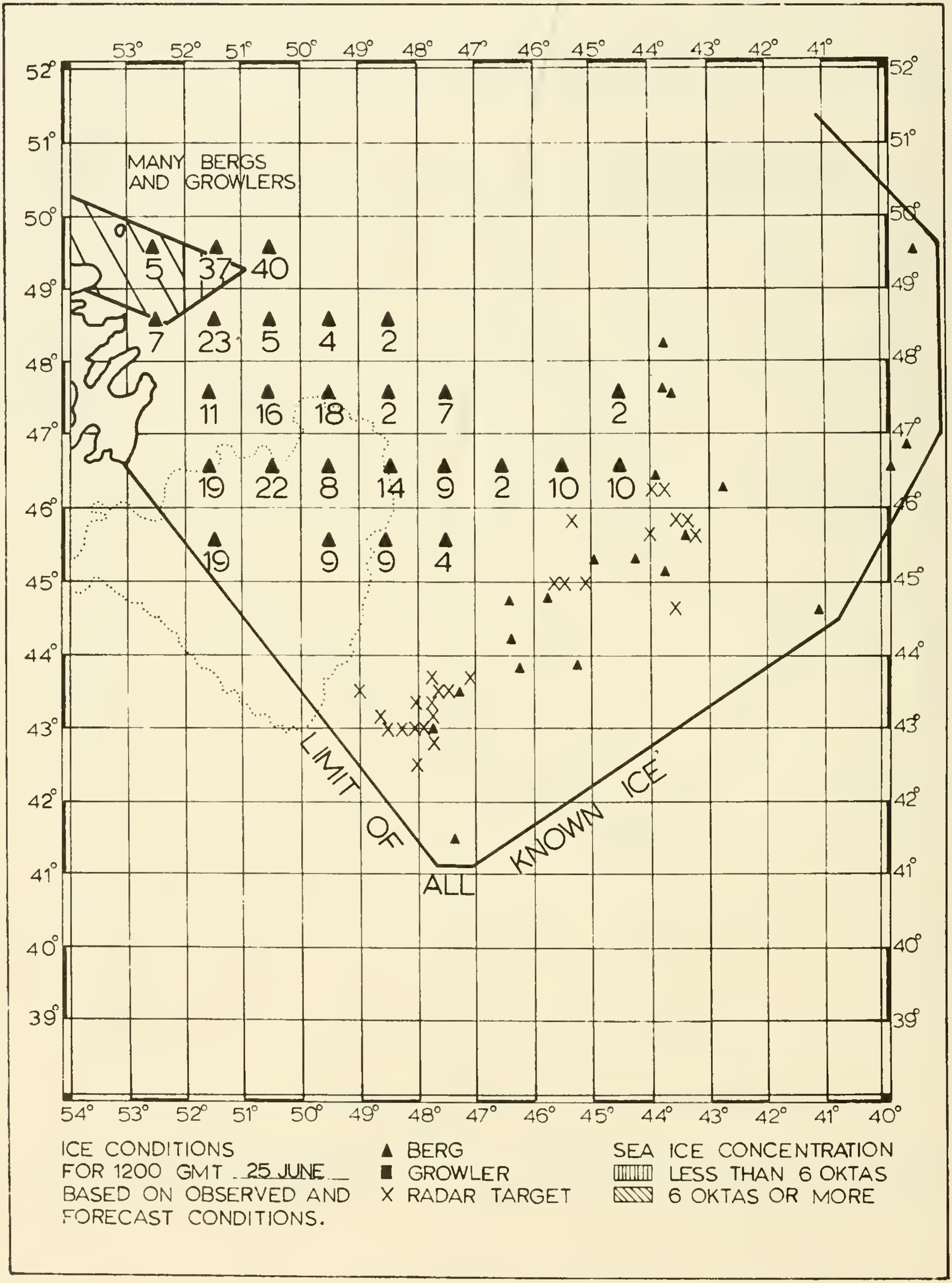

Figure 18.—Ice Conditions, 1200 GMT 25 June 1974.

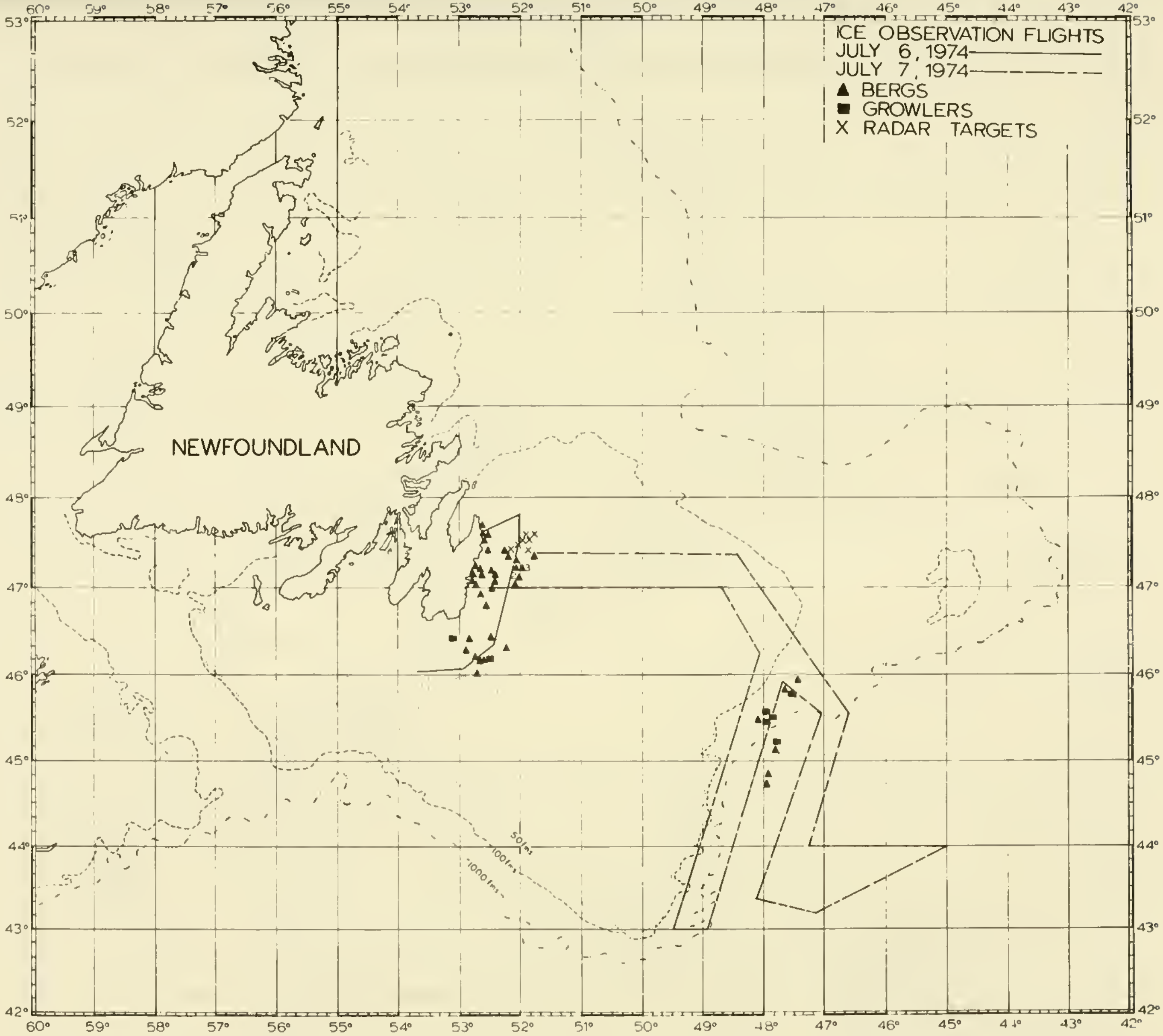

FIGURE 19.—Ice Reconnaissance Flights, 6 and 7 July 1974.

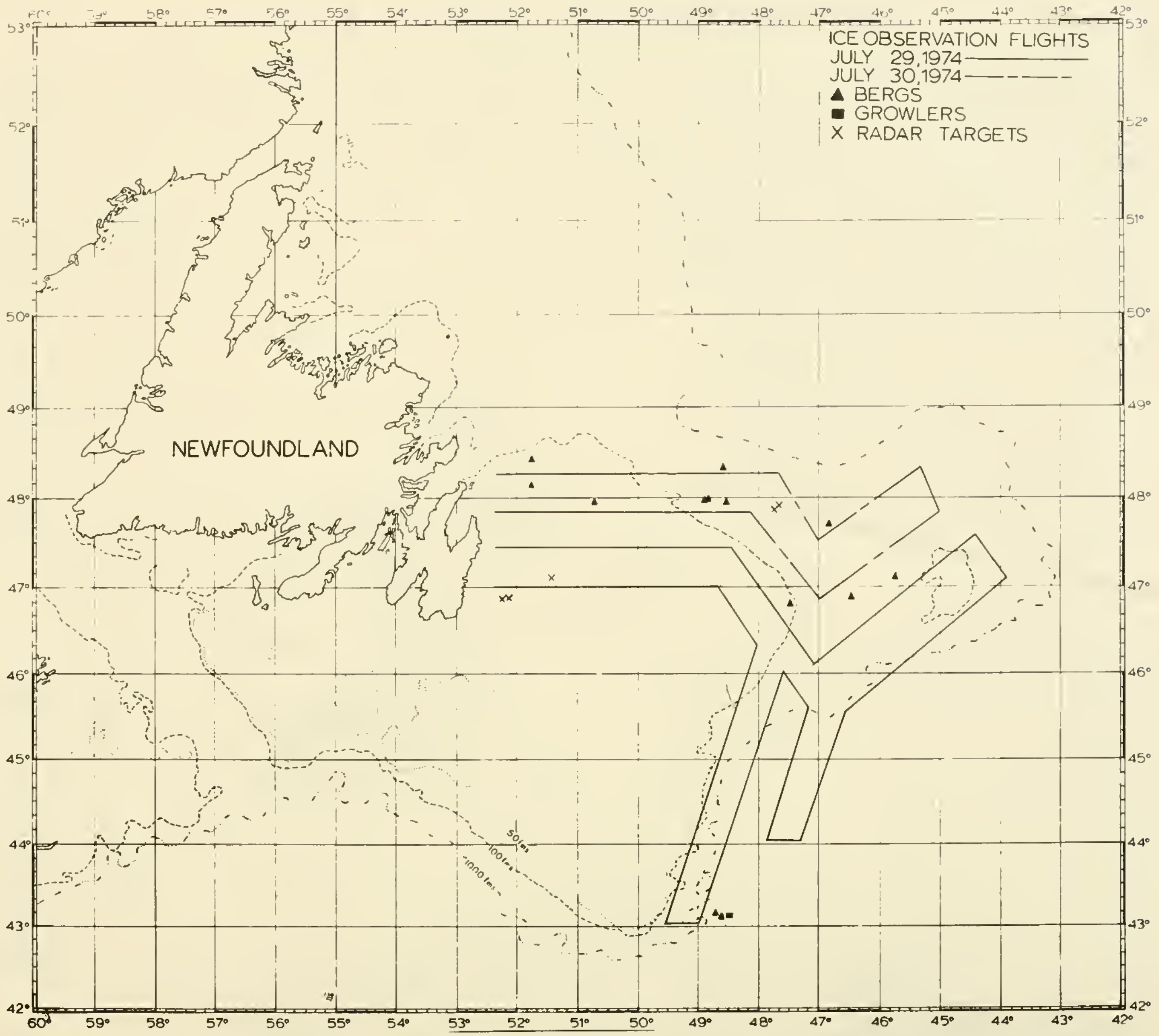

FIGURE 20.—Ice Reconnaissance Flights, 29 and 30 July 1974.

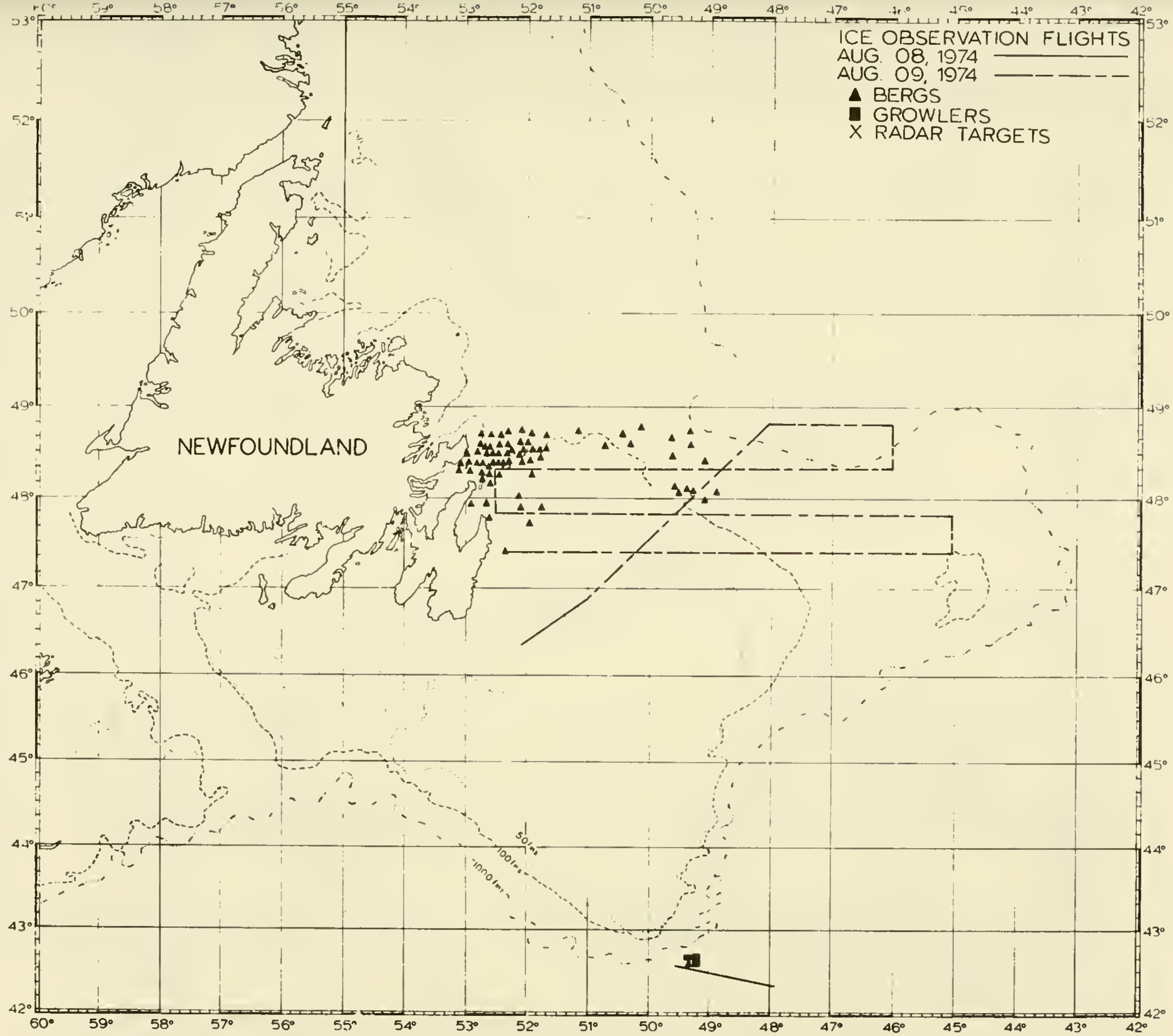

FIGURE 21.—Ice Reconnaissance Flights, 8 and 9 August 1974.

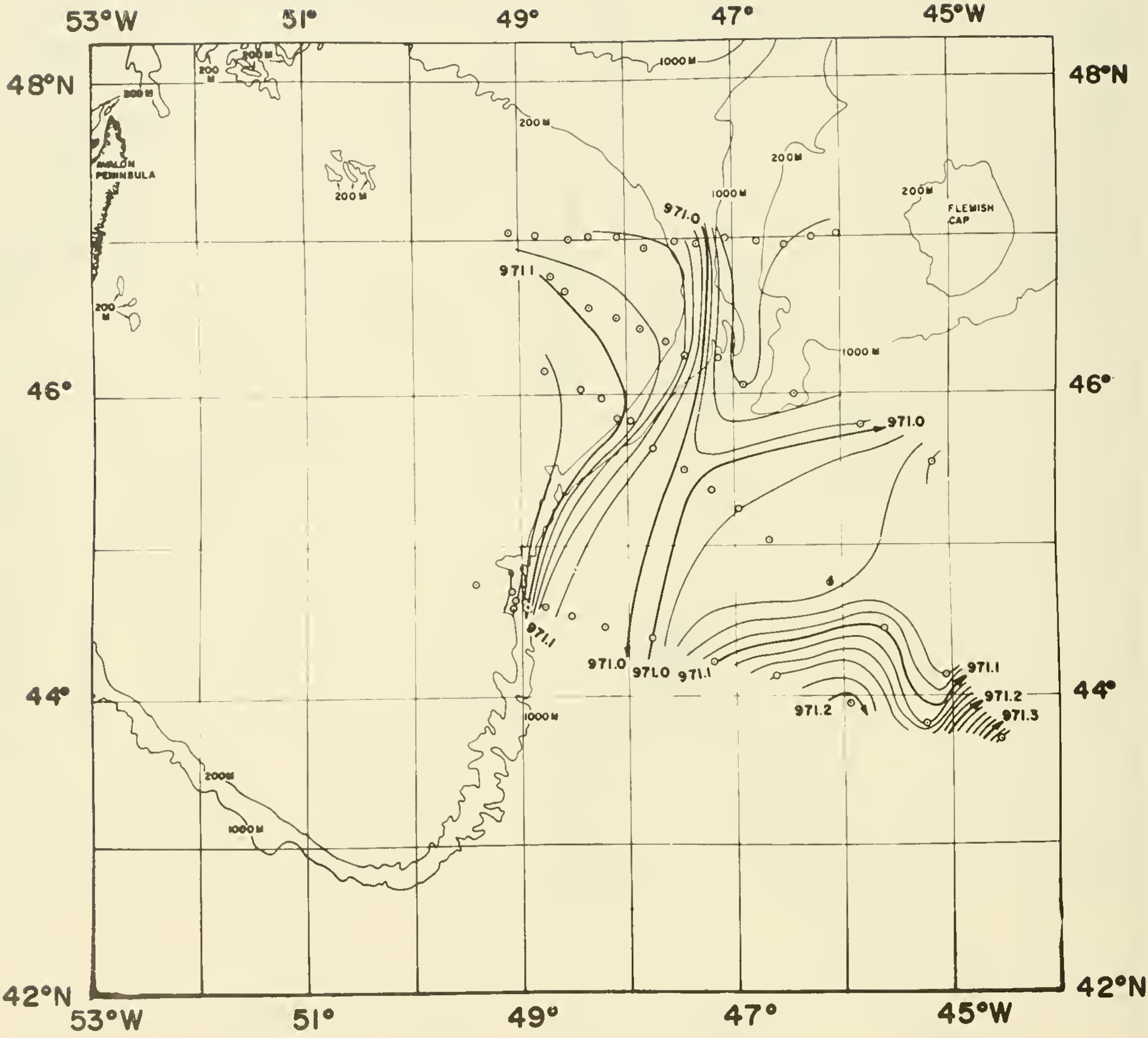

Figure 22.—Dynamic Topography of the Sea Surface with reference to the 1000 Decibar Level. (8–15 April 1974)

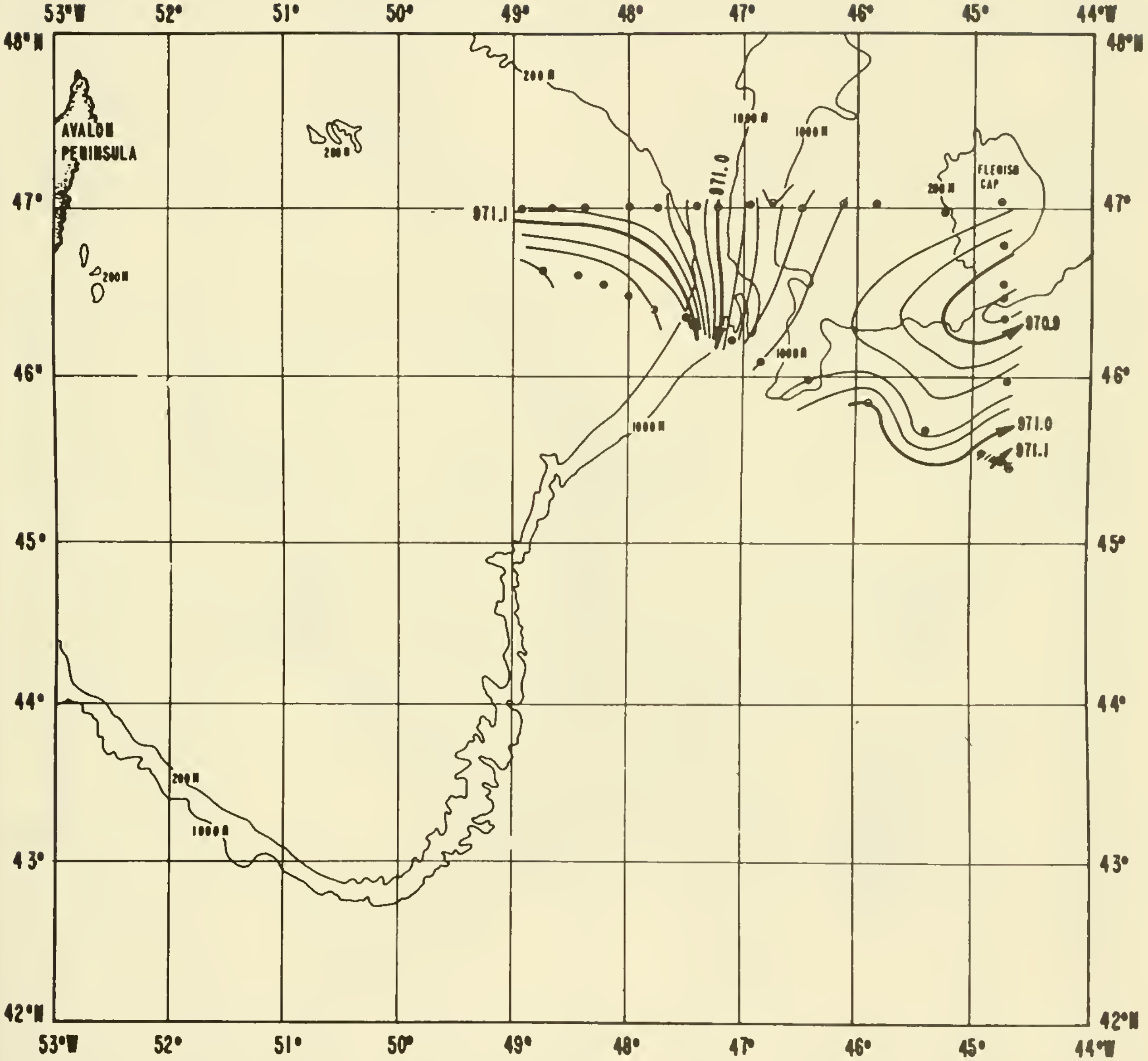

FIGURE 23.—Dynamic Topography of the Sea Surface with reference to the 1000 Decibar Level. (29 April–2 May 1974)

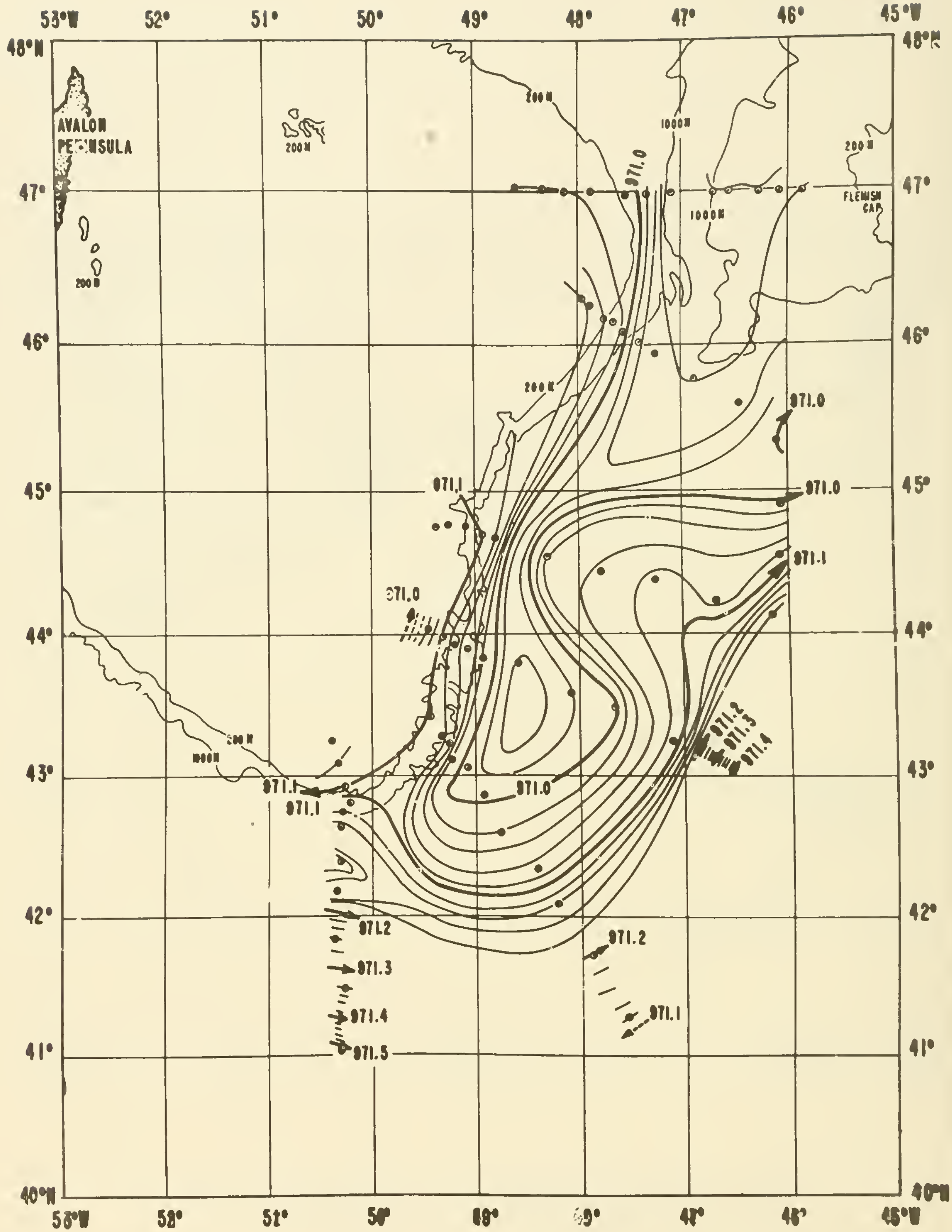

FIGURE 24.—Dynamic Topography of the Sea Surface with reference to the 1000 Decibar Level. (9–17 June 1974)

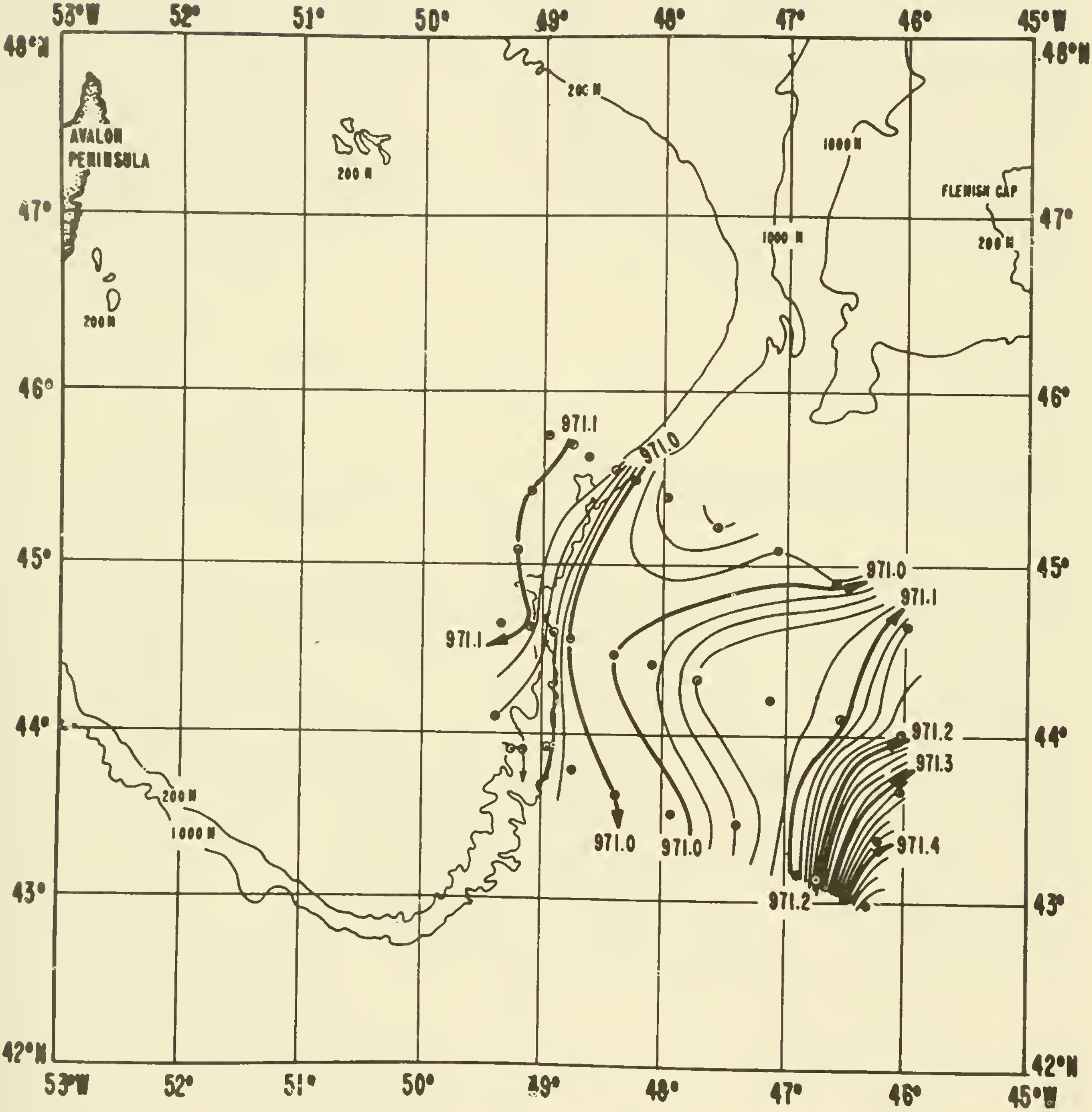

FIGURE 25.—Dynamic Topography of the Sea Surface with reference to the 1000 Decibar Level. (29 June–3 July 1974)

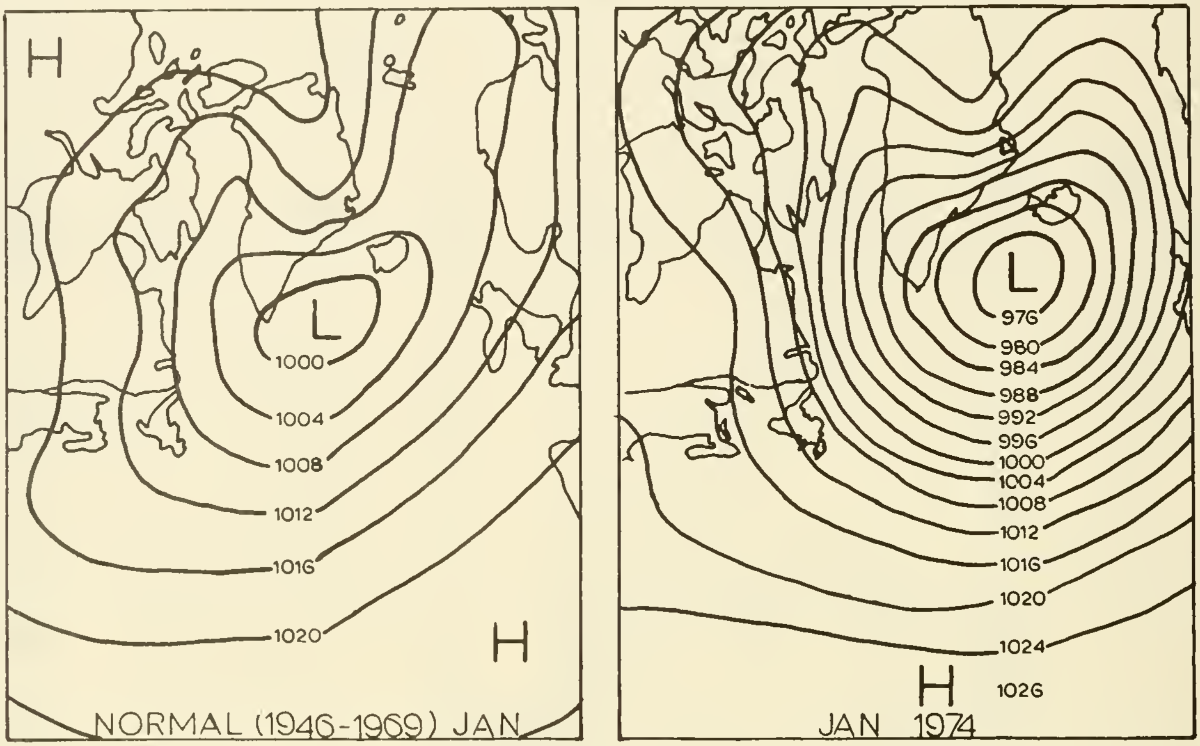

Figure 26a.—January Normal and 1974 Monthly Average Surface Pressure in mbs Relative to 1000 mbs.

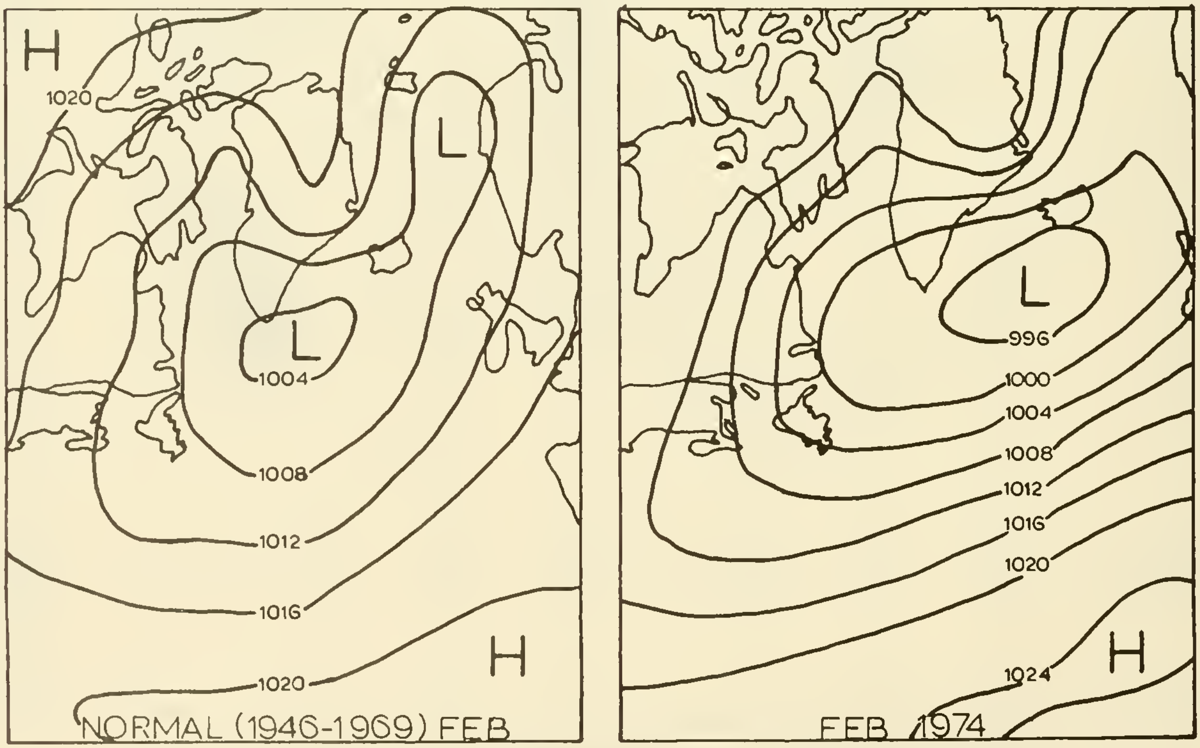

Figure 26b.—February Normal and 1974 Monthly Average Surface Pressure in mbs Relative to 1000 mbs.

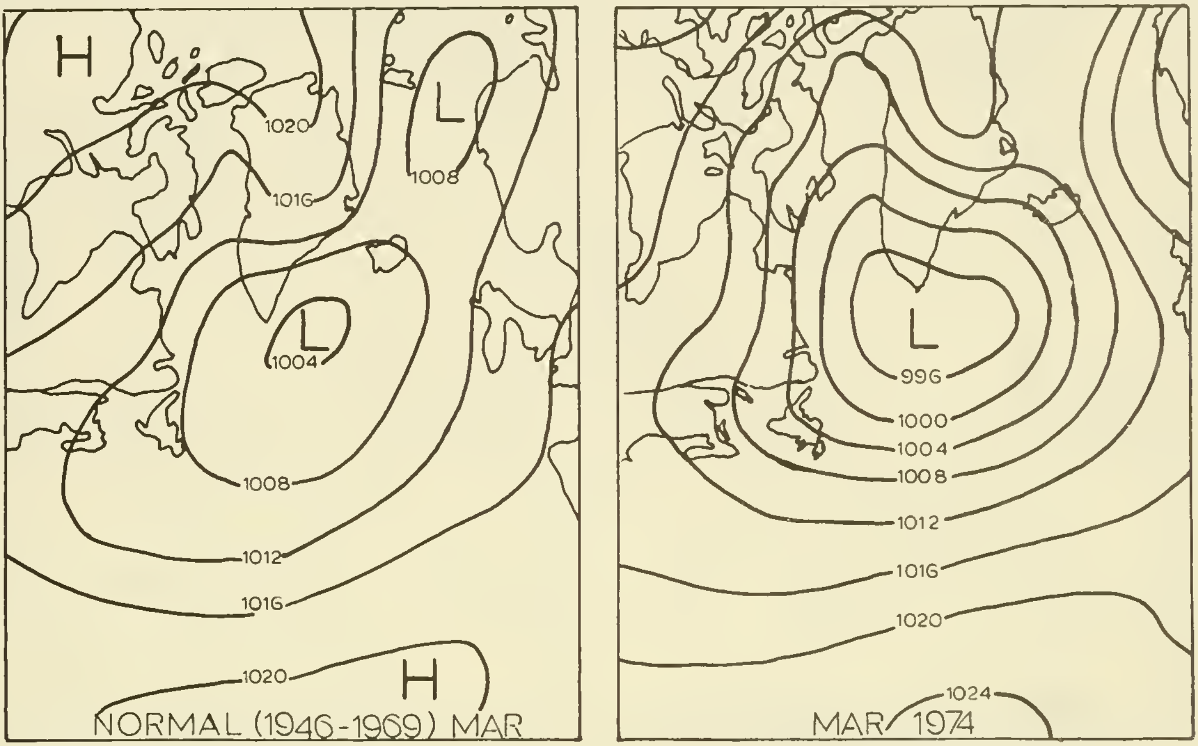

Figure 26c.—March Normal and 1974 Monthly Average Surface Pressure in mbs Relative to 1000 mbs.

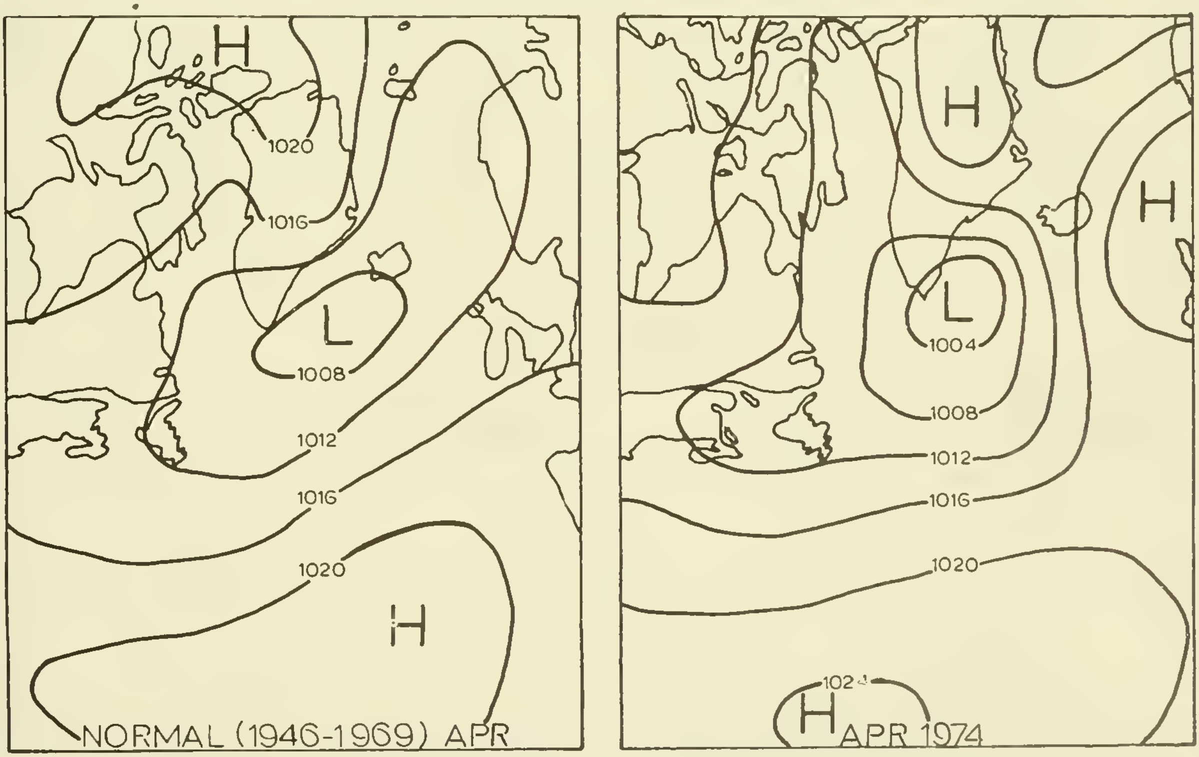

Figure 26d.—April Normal and 1974 Monthly Average Surface Pressure in mbs Relative to 1000 mbs.

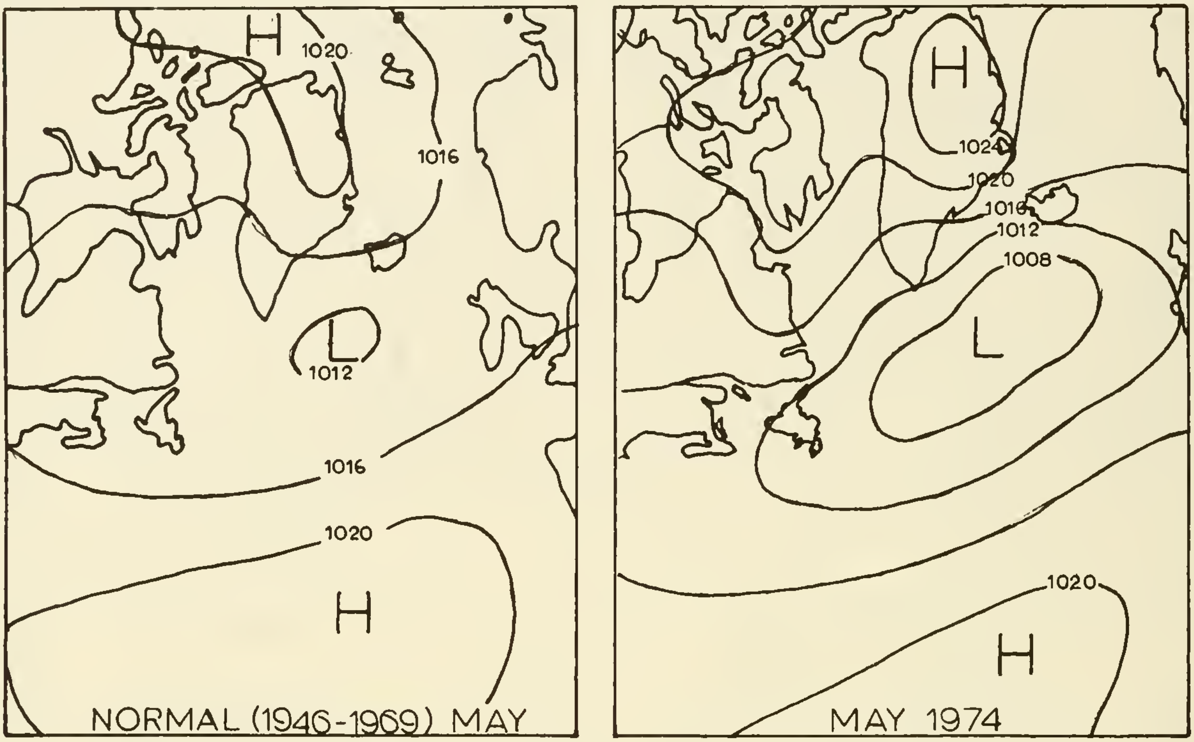

Figure 26e.—May Normal and 1974 Monthly Average Surface Pressure in mbs Relative to 1000 mbs.

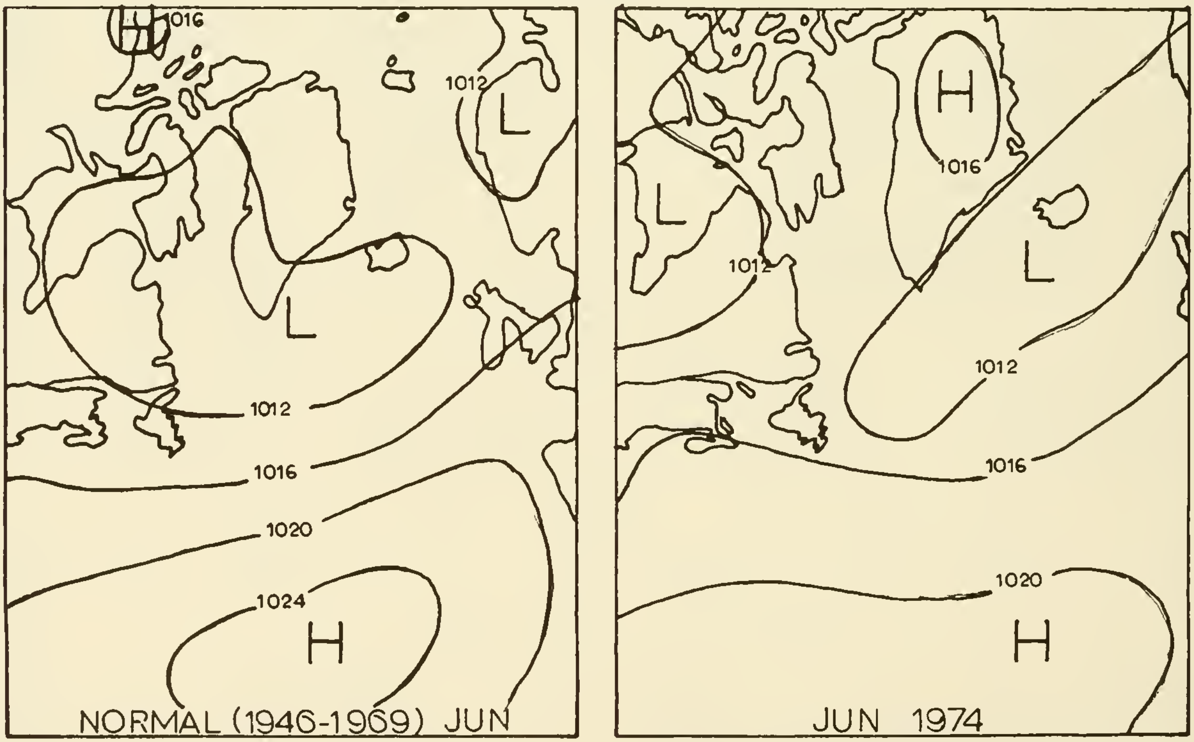

Figure 26f.—June Normal and 1974 Monthly Average Surface Pressure in mbs Relative to 1000 mbs.

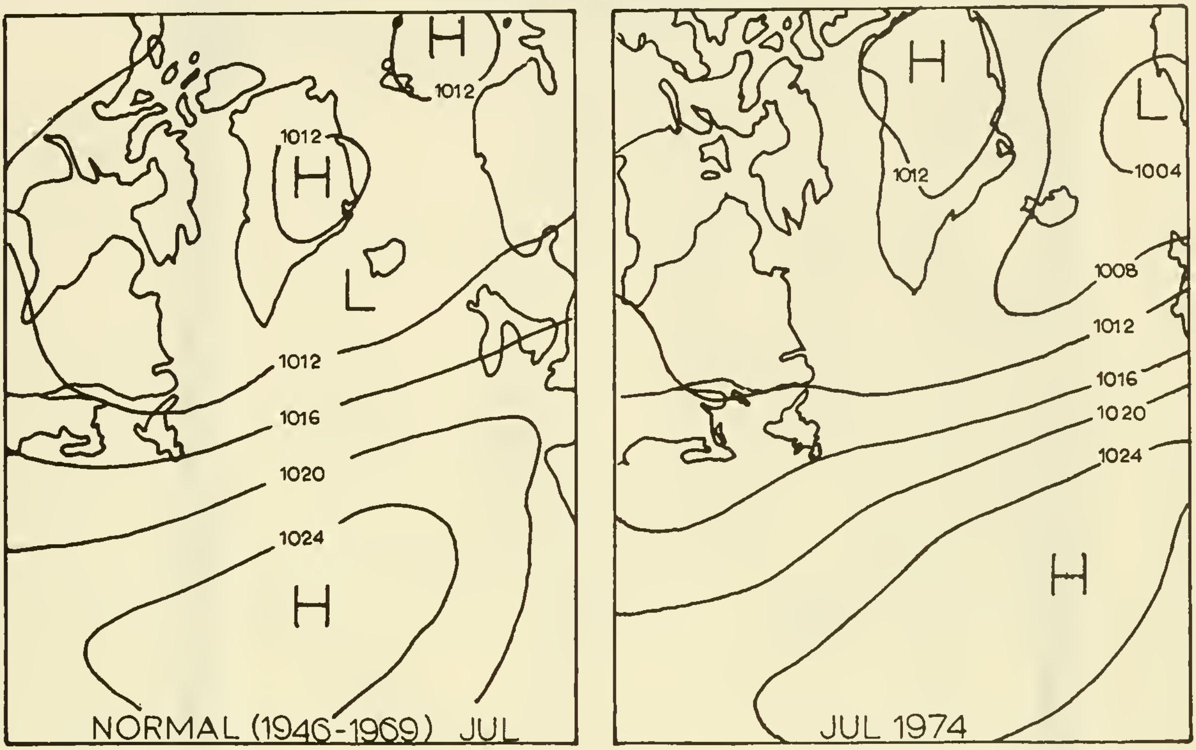

Figure 26g.—July Normal and 1974 Monthly Average Surface Pressure in mbs Relative to 1000 mbs.

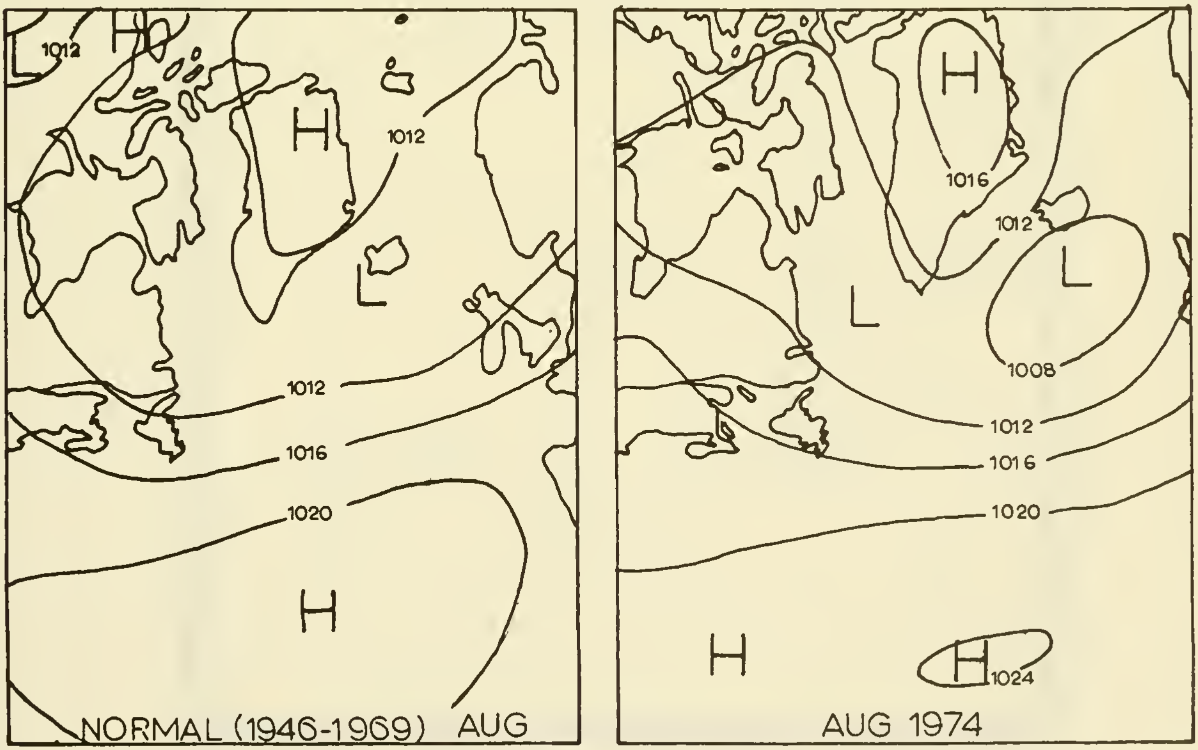

Figure 26h.—August Normal and 1974 Monthly Average Surface Pressure in mbs Relative to 1000 mbs.

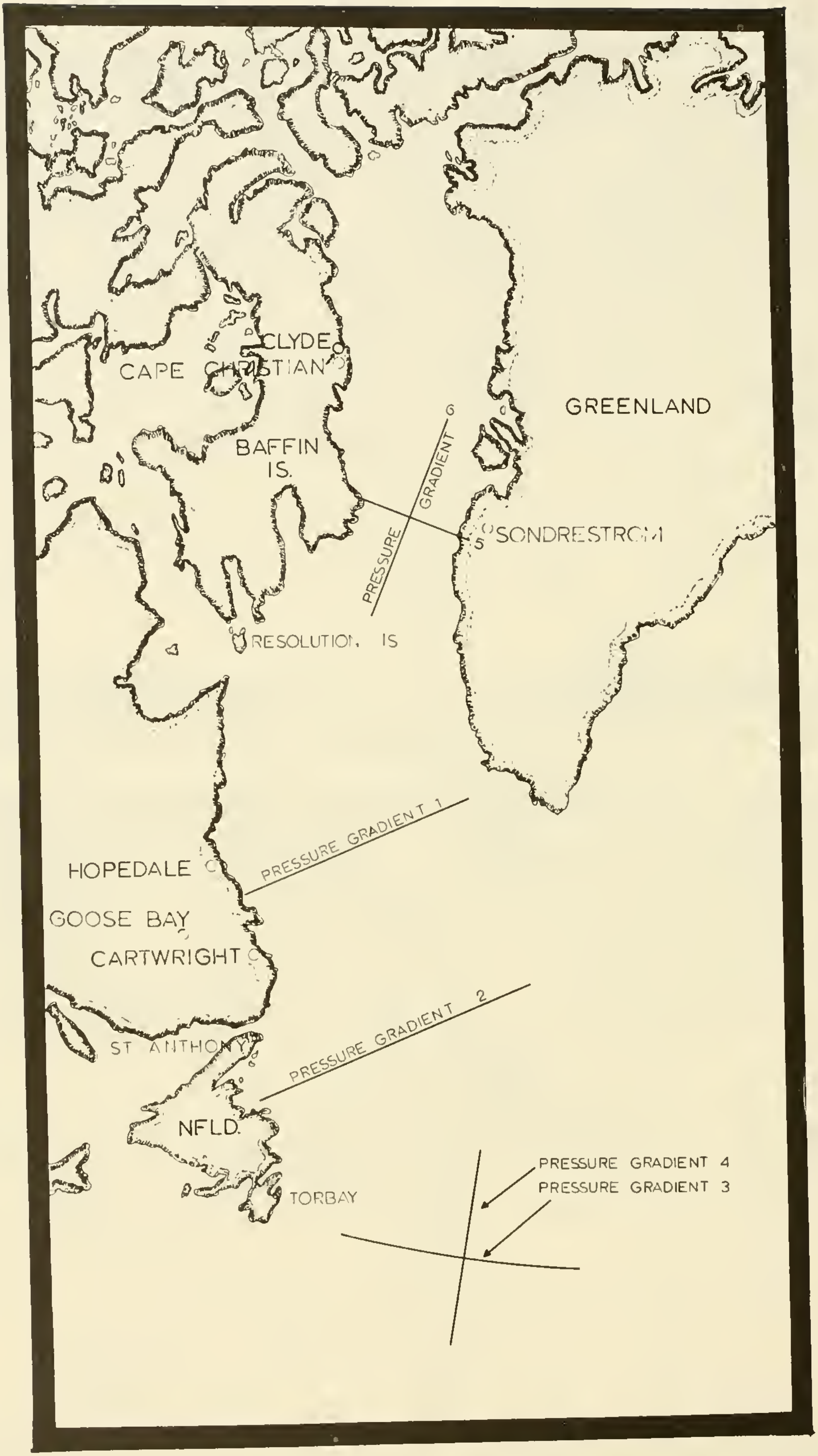

FIGURE 27.—Pressure Gradients Monitored by International Ice Patrol.

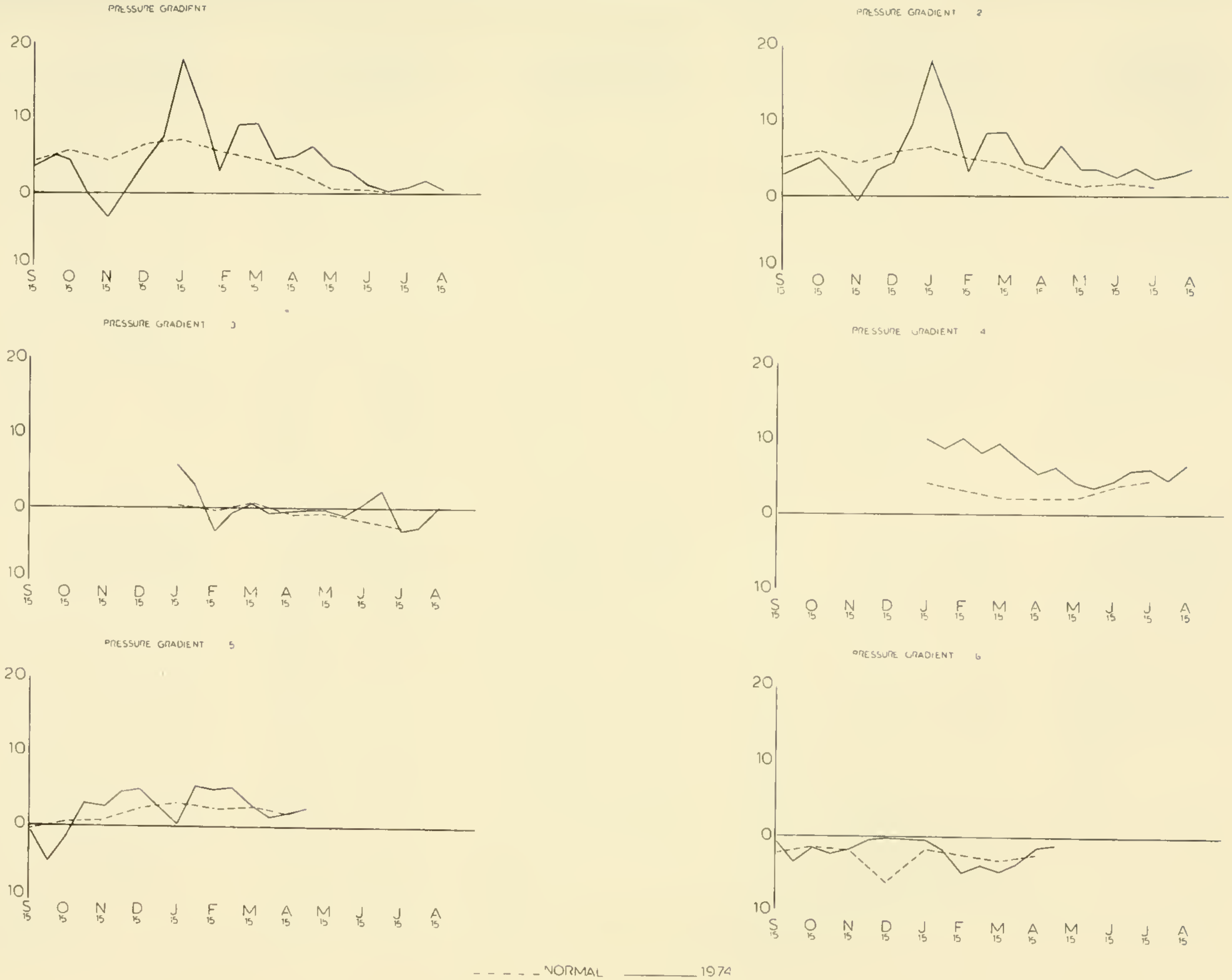

FIGURE 28.—Pressure Gradients 1–6, 1974 Season.

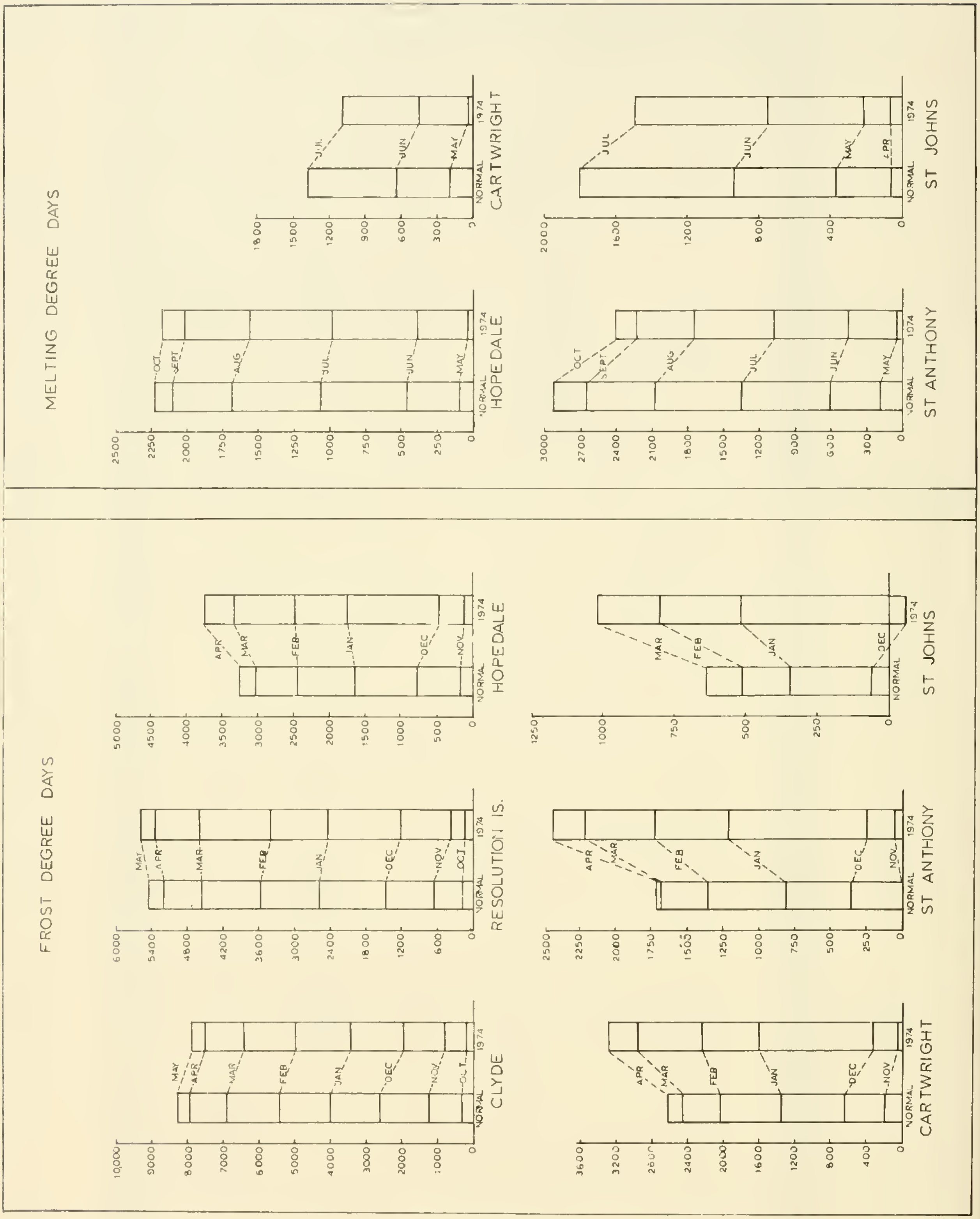

FIGURE 29.—Frost Degree Day and Melt Degree Day Accumulations Calculated from Monthly Mean Fahrenheit Air Temperatures.

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DEPARTMENT OF TRANSPORTATION

COAST GUARD

BULLETIN NO. 61 U.S Coast Guard

Report of the International Ice Patrol Service in the North Atlantic Ocean

SEASON OF 1975

CG-188-30

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Bulletin No. 61

REPORT OF THE INTERNATIONAL ICE PATROL SERVICE IN THE NORTH ATLANTIC OCEAN

Season of 1975

CG-188-30

FOREWORD

Forwarded herewith is Bulletin No. 61 of the International Ice Patrol describing the Patrol's services, and ice observations and conditions during the 1975 season.

N. C. VENZKE
Chief, Office of Operations

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PREFACE

This report is the 61st in a series of annual reports on the International Ice Patrol Service in the North Atlantic Ocean. It contains information on Ice Patrol organization, communications and operations, ice and environmental conditions and their relationship in 1975, and research conducted this year.

The authors of this report, Commander Albert D. SUPER, Lieutenant Harold G. KETCHEN and Marine Science Technician First Class Charles W. JENNINGS, all USCG, acknowledge ice and weather data provided by the Canadian Department of the Environment, sea surface temperature data provided by Commander, Maritime Command, Halifax, weather data provided by the U.S. National Weather Service, weather and oceanographic data provided by the U.S. Coast Guard Oceanographic Unit. Acknowledgement is also made to Yeoman Second Class Terry L. GEST, USCG, Chief Marine Science Technicians Walter P. ARK and Neil O. TIBAYAN, USCG, Marine Science Technician First Class Raymond J. EVERS, USCG, Marine Science Technician First Class Robert N. HILDEBRAND, USCG, and Marine Science Technician Third Class Paul A. LeBRUN, USCG, for their assistance in the preparation of the manuscript and illustrations for this report.

The continued assistance and cooperation provided by the Canadian Coastal Radio Station St. John's/VON in the relay of operational and administrative messages is gratefully acknowledged.

INTERNATIONAL ICE PATROL, 1975

The 1975 International Ice Patrol Service in the North Atlantic Ocean was conducted by the United States Coast Guard under the provisions of Title 46, United States Code, Sections 738, 738a through 738d, and the International Convention for the Safety of Life at Sea, 1960, Regulations 5 through 8. The International Ice Patrol is a service for observing and disseminating information on ice conditions in the Grand Banks Region of the Northwest Atlantic Ocean. During the ice season, the southeastern, southern and southwestern limits of the regions of icebergs in the vicinity of the Grand Banks of Newfoundland are guarded for the purpose of informing passing ships of the extent of this dangerous region. The International Ice Patrol also studies ice conditions in general with emphasis on the formation, drift and deterioration of icebergs, and assists ships and personnel requiring aid within the limits of operation of the Ice Patrol forces.

The International Ice Patrol is directed from the Ice Patrol Office located at the U.S. Coast Guard Base, Governors Island, New York. The Office gathers ice and environmental data from a variety of sources, maintains an ice plot, forecasts ice conditions, prepares the twice-daily Ice Bulletin, replies to requests for special ice information, and executes operational control of the Aerial Ice Reconnaissance Detachment, the Ice Patrol oceanographic cutter, and the Surface Patrol cutter when assigned.

Vice Admiral William F. REA, U.S. Coast Guard, was Commander, International Ice Patrol. Commander Albert D. SUPER, U.S. Coast Guard, was directly responsible for the management of the Patrol.

Preseason Ice Patrol northern reconnaissance missions were made in January and February, 1975 to assess the potential for season severity and locate the southern most icebergs. For the second consecutive year, Ice Patrol utilized St. John's, Newfoundland for its base of operations. The Aerial Ice Reconnaissance Detachment deployed to St. John's on March 17 and returned to the United States on June 23, 1975.

The 1975 Ice Season officially commenced at 0000 GMT, March 4, when the first Ice Bulletin was issued, and continued until the final bulletin was issued at 0000 GMT, June 24, 1975. The twice-daily Ice Bulletins were broadcast by the International Ice Patrol Communications Station Boston/NIK, U.S. Naval Radio Station Norfolk/NAM, Canadian Maritime Command Radio Station Mill Cove/CFH, and Canadian Coastal Radio Station at St. John's/VON. A facsimile ice chart was broadcast from Boston once each day. Iceberg information was also included on the regularly scheduled radio facsimile broadcasts of Naval Radio Norfolk/NFAX, CANMARCOM/CFH, Radio Bracknell/GFE, Radio Hamburg/DGC and Radio Quickborn/DGN.

The U.S. Coast Guard Cutter EVERGREEN, Commanded by Commander Martin J. MOYNIHAN, U.S. Coast Guard, conducted oceanographic and research cruises for the Ice Patrol from April 2 to 29 and May 20 to July 10, 1975. During these cruises EVERGREEN obtained oceanographic data along Ice Patrol standard sections to provide operational ocean current information, conducted iceberg drift studies, and deployed oceanographic current meters. The U.S. Coast Guard Cutter SHERMAN, Commanded by Captain James P. RANDLE, U.S. Coast Guard, deployed from June 7 to 25, 1975 and joined EVERGREEN for research studies of iceberg drift and deterioration. The Ice Reconnaissance Detachment participated in this phase by locating suitable icebergs for the studies and, on one occasion, dropped ice penetrometers into an iceberg to evaluate this method of affixing an instrument package or beacon to an iceberg. During this second cruise EVERGREEN also conducted two intensive oceanographic surveys to provide data for a Labrador Current model under development.

A surface patrol was not required this season.

During the 1975 Season an estimated 101 icebergs drifted south of 48°N.

AERIAL ICE RECONNAISSANCE

During the period September 1, 1974 to August 31, 1975 a total of 71 ice observation flights were flown. Preseason flights made in January and February accounted for 12 flights, and the remaining 59 flights were made during the ice season. There was no requirement for post-season flights. The objective of the preseason surveys was to study the iceberg distribution patterns in the Labrador Sea, to evaluate the iceberg potential of the developing ice season and to locate the southernmost icebergs. The season flight objectives were to locate the southwestern, southern, and southeastern limits of icebergs, to evaluate the short-term iceberg potential of the waters immediately north of the Grand Banks, and occasionally to study the iceberg distribution along the Labrador Coast. Several flights during the season were devoted to test and evaluation of a Side-Looking Airborne Radar (SLAR) in the development of an all-weather iceberg detection system. The flight statistics shown in Table 1 do not include the flight time required to make the passages between U.S. Coast Guard Air Station, Elizabeth City, North Carolina and the operating base for crew relief or aircraft maintenance.

Aerial ice reconnaissance was accomplished by U.S. Coast Guard HC-130-B (Lockheed Hercules) four-engine aircraft from the Coast Guard Air Station at Elizabeth City, North Carolina.

Table 1—Aerial Ice Reconnaissance Statistics September 1974 through August 1975

Month	*Number of Flights*	*Flight Hours*
PRESEASON		
September-December	0	0
January	4	22.5
February	3	14.2
March	5	36.2
Preseason total	12	72.9
SEASON		
March	7	51.1
April	14	89.3
May	27	161.0
June	11	59.0
July	0	0
August	0	0
Season total	59	360.4
Annual total	71	433.3

During the iceberg season, the aircraft operated out of Torbay Airport, St. John's, Newfoundland.

On March 17 the Ice Reconnaissance Detachment deployed to St. John's from Elizabeth City. The main base of operation for the Detachment remained at St. John's until June 23 when they returned to Elizabeth City. Aircraft, crew and ice observers were exchanged at approximately three week intervals.

COMMUNICATIONS

Ice Patrol communications included ice reports, environmental conditions, Ice Bulletins, special ice advisories, a daily facsimile chart, and the administrative and operational traffic necessary to the conduct of the Patrol. The Ice Bulletin was transmitted by teletype from the Third Coast Guard District Communications Center in New York twice each day to over 30 addresses, including those radio stations which broadcast the Bulletin. These stations were the U.S. Coast Guard Communications Station Boston/NIK/NMF, U.S. Naval Radio Station Norfolk/NAM, Canadian Coastal Radio Station, St. John's/VON and Canadian Forces Maritime Command Radio Station, Mill Cove/CFH.

Coast Guard Communications Station Boston transmitted the Bulletin by CW at 0018 GMT on 5230 and 8502 kHz and at 1218 GMT on 8502 and 12750 kHz. After a 2-minute series of test signals the transmissions were made at 25 words per minute and then repeated at 15 words per minute. Coast Guard Communications Station Boston/NIK also transmitted a daily radio facsimile broadcast depicting the locations of icebergs and sea ice at 1600 GMT simultaneously on 8502 and 12750 kHz at a drum speed of 120 revolutions per minute.

Ice Bulletins were also broadcast via CW twice daily by U.S. Naval Radio Station Norfolk/NAM at 0430 and 1700 GMT on 88.0 (except the Tuesday 1700 GMT transmission was made on 134.9 kHz), 8090, 12135, 16180, 20225 (1700 GMT only) and 25590 (1700 GMT only) kHz; Canadian Maritime Command Radio Station Mill Cove/CHF at 0130 and 1330 GMT on 438 (except the 1330 GMT transmission the second Thursday each month), 4356.5, 6449.5, 8662, 12984, 17218.4 and 22587 (on request) kHz; and Canadian Coastal Radio Station St. John's/VON at 0000 and 1330 GMT on 478 kHz. Radio facsimile broadcasts that included the limits of icebergs were made by Fleet Weather Central Norfolk/NFAX at 1805 GMT on 4957, 8080, 10865, 16410 and 20015 kHz; Canadian Maritime Command Radio Station Mill Cove/CHF at 0000 and 1200 GMT on 133.15, 4271, 9890, 13510 and 17560 kHz; Radio Station Bracknell/GFE at 1400 GMT on 4782, 9203, 14436 and 18261 kHz; and Radio Station Hamburg/DGC and Radio Station Pinneburg/DGN at 0905 and 2145 GMT on 3695.3 and 13627.1 kHz. All radiofacsimile broadcasts were made at a drum speed of 120 revolutions per minute.

Special broadcasts were made by Canadian Coastal Radio Station St. John's/VON as required when icebergs were sighted outside the limits of ice between regularly scheduled broadcasts. These transmissions were preceded by the International Safety Signal (TTT) on 500 kHz.

Merchant ships calling to transmit ice sightings, weather and sea surface temperatures were requested to use the regularly assigned international call signs of the Coast Guard Ocean Weather Station HOTEL, East Coast AMVER Radio Stations, or Canadian Coastal Radio Station St. John's/VON. All Coast Guard Stations were alert to answer NIK/NIDK calls, if used.

Ice information services for the Gulf of St. Lawrence, as well as the approaches and coastal waters of Newfoundland and Labrador, were provided by the Canadian Department of the Environment from December until approximately

Table 2—Communications Statistics

Number of ice reports received from ships	192
Number of ships furnishing ice reports	101
Number of ice reports received from commercial aircraft	5
Number of sea surface temperature reports	1050
Number of ships furnishing sea surface temperature reports	57
Number of ships requesting special ice reports	10
Number of NIK Ice Bulletins issued	224
Number of NIK facsimile broadcasts	111

late June. Ships obtained ice information by contacting the Ice Operations Officer, Sydney, Nova Scotia via Sydney Marine Radio/VCO or Halifax Marine Radio/VCS.

Communications statistics for the period 1 September 1974 through 31 August 1975 are shown in Table 2.

Of the fifty-seven ships furnishing Ice Patrol with sea surface temperature information the eleven most outstanding contributors were:

USCGC SHERMAN/NMMJ
M/V ATLANTIC SPAN/SLPN
M/V HURON/CGXY
M/V LONDON TRADITION/MXYC
M/V STADT BREMEN/DECP
M/V MINERAL SERAING/ONMO
M/V STADT WOLFSBURG/DCWE
M/V LONDON PRIDE/GOSH
USNS NEPTUNE/NGUB
M/V AMSTEL HOF/PCPL
M/V NORSE FALCON/GUMW

Table 3—Estimated Number of Icebergs South of Latitude 48 N, Season 1975

	SEPT	*OCT*	*NOV*	*DEC*	*JAN*	*FEB*	*MAR*	*APR*	*MAY*	*JUN*	*JUL*	*AUG*	*TOTAL*
1975	1	0	0	0	0	24	41	10	20	5	0	0	101
TOTAL 1946–1975	10	2	4	11	64	261	1035	2926	2830	1716	480	100	9,439
AVERAGE 1946–1975	0	0	0	0	2	9	35	98	94	57	16	3	315
TOTAL 1900–1975	256	109	110	91	184	712	3137	7771	9913	5234	1676	489	29,682
AVERAGE 1900–1975	3	1	1	1	2	9	41	102	130	69	22	6	391

ICE CONDITIONS, 1975 SEASON

September-December 1974

After the close of the 1974 Season, the second heaviest on record, a few icebergs reached the waters immediately north of the Grand Banks. The southernmost of these was reported on 11 September as a large berg in position 47°59′N, 45°48′W. On 8 October, a merchant ship sighted an iceberg "140 miles after leaving Cape Race". Ice Patrol was unable to contact the reporting ship to confirm this report and no other reports of this iceberg were received. Otherwise, there was no ice reported south of 51°N from September through December. By the first of September all sea ice had melted in Baffin Bay. New ice did not start forming again until late September along the east coast of Ellesmere Island and in isolated bays and coves along the Baffin Island coast. Freeze-up began in earnest in Baffin Bay in mid-October, with a very rapid ice growth during late October through the first half of November. Slightly above average growth rates continued for the remainder of the year. On 20 November, a U.S. Navy ice reconnaissance flight with an Ice Patrol observer on board covered the waters along the coast of Labrador and southern Baffin Island. Only three icebergs were sighted, all north of Cape Chidley. The following day, an aerial survey was completed in central Baffin Bay south of 76°N. When compared to a similar survey in October, 1970, there were relatively few bergs observed south of 73°N. On 22 November, the east coast of Greenland was surveyed between 65°30′N and 76°N. A surprising number of large icebergs were sighted. Under ideal conditions, some of these bergs would survive a drift from East Greenland across the Labrador Sea or Davis Strait and then south to the Grand Banks. By the end of December, sea ice cover extended from the coast of Greenland near Sondrestrom Fjord in a southeasterly direction to about 100 nautical miles east of Hudson Strait, then southerly along the Labrador coast to 52°30′N (just north of the Strait of Belle Isle). Very open pack new ice developed over the eastern half of the Strait and new ice was beginning to form in some sheltered shallows of Notre Dame Bay and Newfoundland's Northern Peninsula.

January 1975

Only one iceberg (53°05′N, 52°05′W) was reported by maritime traffic in January. Although retarded somewhat during the first week of January, the overall trend was for normal ice growth east and northeast of Newfoundland. By the middle of the month, the Strait of Belle Isle was covered and ice was spreading into Newfoundland waters. Notre Dame Bay remained ice free until near the end of the month when new and grey ice were first observed. By the end of January, new ice had formed in Bonavista Bay and the heavier Labrador pack was moving south of 51°N. A preseason survey was conducted January 20–28 along the coasts of Labrador and Baffin Island as far north as Cape Christian and across Davis Strait to the west Greenland coast (See Figure 1). Iceberg populations south of Davis Strait were estimated to be about one half the 1963–1974 average. There were no icebergs sighted during the flights south of Hamilton Inlet and only four icebergs between 54°N and 55°N. The southernmost of these were two small bergs located at 54°23′N 54°18′W and 54°25′N, 54°37′W. The latitudinal iceberg distribution is illustrated graphically in figure 2. No large icebergs were sighted south of Cape Chidley and the bergs located north of there were small and very weathered. Considering the lack of sizable icebergs, the small total population and the northern position of the main iceberg grouping, it was predicted that the 1975 iceberg season would see a below normal number of icebergs reaching the Grand Banks and the season would begin later than usual.

February 1975

During the first half of February, three iceberg reports were received. The southernmost, 50°18′N 51°08′W, was reported as a large berg on 8 February. Early February saw a very rapid south-southeastward spread of pack ice. Ice conditions on the Grand Banks equalled those of the same period last year, the most severe sea ice year in decades. A mean offshore ice drift during the period prevented any serious ice congestion along Newfoundland's east coast. Ice growth continued during the last half of the month, although at a decreased rate. Ice drifting south added to the pack off Newfoundland. Although the ice cover was above normal, thicknesses were much less than in 1974. By the end of February, sea ice had reached a southeastern limit roughly defined by a line from 45°15′N, 48°20′W to 46°10′N, 46°35′W. Iceberg sightings became more numerous as favorable environmental conditions speeded the few icebergs south toward the Grand Banks. Late February preseason flights, 24 February to 12 March (See Figure 3), revealed only 66% of the normal iceberg population south of Davis Strait along the Baffin Island and Labrador coasts. As in the January surveys, there was a predominance of small icebergs in these upstream regions. The latitudinal iceberg distribution is illustrated graphically in figure 4. A strong southerly flow and an apparent greater than normal mass transport along the Labrador coast from mid-January through February brought the icebergs from coastal Labrador onto the Grand Banks considerably earlier than expected. The southernmost, a small berg was sighted in position 43°58′N, 47°40′W on 1 March. The easternmost iceberg of the month was reported on 25 February as a small iceberg (47°08′N, 47°20′W). Although numbers were low and sizes small, an estimated 24 icebergs had already crossed 48°N during February. This is well above the 75 year average of 9 iceberg crossings in February.

March 1975

With the unexpected acceleration in the southward drift of icebergs during February, a number of icebergs began to exit the southeast cover of sea ice posing a threat to trans-Atlantic traffic. Considering this, the 1975 Ice Patrol service was officially started on 4 March. Figure 5 shows the iceberg locations as observed during aerial reconnaissance flights on 1 and 7 March. These two flights established the limits of all known ice for the start of the season. The first regular season deployment of the Ice Reconnaissance Detachment occurred on 17 March with aircrew and ice observers moving to St. John's, Newfoundland. On 18 and 19 March, consecutive ice reconnaissance flights (Figure 6) revealed 30 icebergs and 10 growlers below 48°N, but most of these were relatively small in size and showed signs of advanced stages of deterioration. Although sea ice cover was more extensive than normal during the first half of March, the ice east of Newfoundland continued to be thin and of very loose composition. Predominant mild wind flow from the southwest caused early deterioration and recession of the sea ice limits beginning in mid-month. On 26 March, no heavy concentrations of sea ice existed below 48°N although some brash and small cakes of diffused ice extended to 45°N. By the end of March, the concentrated pack had retreated to approximately 49°N with only very diffuse ice extending to 45°N (figure 8). The southernmost iceberg for the month was observed on 27 March (42°50′N, 49°20′W). This was followed three days later by the sighting of a growler, believed to be the same piece of ice, in position 42°38′N, 49°30′W. A total of 41 icebergs crossed 48°N during March. This peak in the iceberg population on the Grand Banks occurred a full month earlier than usual and accounted for over 40% of the total number of icebergs that would cross 48°N during 1975. One unusual berg sighting was reported outside the Ice Patrol area by the Icelandic cargo vessel SKAFTAFEIL on 28 March. This iceberg was encountered some 400 miles southeast of Cape Farewell, Greenland in position 55°15′N, 35°04′W.

April 1975

The sea ice edge off Newfoundland/Labrador continued to move northward during April, resulting in increased iceberg melt rates for the already rapidly decaying population. The southernmost berg (42°36′N, 50°03′W) during the month was last seen on 1 April. The southernmost piece of ice for the 1975 season, a growler, was sighted on 4 April in position 41°44′N, 48°45′W. A series of flights on 1, 2 and 3 April, averaging better than 80% visual coverage along

the track shown in figure 9, located only 22 icebergs and 12 growlers strung out from 51°N to the Tail of the Banks and east to Flemish Cap. Fifteen (15) of these were already south of 48°N, having crossed during March. They had decayed significantly since previously sighted. Although a few were scattered to the south and east, the major grouping was clustered around 46°30′N, 47°W. By the end of the first week in April, all sea ice was north of 49°N with the concentrated pack north of 50°N and west of 51°W. The southern ice limit consisted of open pack, thin first year. The number of icebergs on the Grand Banks gradually dropped during the month due to the increased melt rate and small supply of upstream icebergs flowing into the area. Flights on 15, 16 and 19 April (See Figure 11) found only 15 icebergs below 48°N, the southernmost being at 44°30′N, and only 11 growlers and one small iceberg between 49°N and 50°N. By 28 April, there were only 28 icebergs and growlers south of 52°N being tracked by the Ice Patrol (See Figure 12). Since the Ice Patrol tends to be conservative in removing icebergs from this plot, some of these icebergs may have been duplicates with slightly different positions from two or more sources, or they may have already completely melted. Only 10 bergs were estimated to have crossed 48°N during the entire month of April, usually the most active iceberg month of the year on the Grand Banks. This number represents only 10% of the long-term normal for April.

May 1975

On the 3rd and 4th of May, flight tracks (figure 13) were flown with reasonably good visibility encountered. A total of 12 icebergs and 15 growlers were sighted south of 48°N, all of these located just to the north or west of the Grand Banks. Repeat sightings have been removed from figure 13. A group of 4 icebergs and 5 growlers, grouped within a 30 mile radius of 42°30′N, 48°30′W, marked the southern limit of all known ice at the time. The western berg of this group (sighted on 5 May), was reported two days later by the British passenger liner ORIANA in position 41°45′N, 47°58′W. This proved to be the southernmost iceberg reported during 1975. On 5 May there was no sea ice south of 51°N or east of 53°W (figure 4). No icebergs were sighted east of 44°W off the Grand Banks in 1975, although a number of bergs were reported in the vicinity of Flemish Cap between 44°W and 46°W, the easternmost of these, a medium iceberg (47°05′N, 44°42′W) and four growlers (out to 47°01′N 44°30′W), were observed on 14 May. Beside these sightings, flights on 13, 14, and 15 May located only two small icebergs (one with a number of growlers) south of 47°30′N (figure 15). Also sighted were a large berg (47°57′N, 49°08′W) and 3 medium and 3 small bergs with growlers off Cape St. Francis, all of which were resighted further south on 20, 22, and 23 May (figure 16). On 19 May, a coastal flight was made along Newfoundland and Labrador coasts up to 56°N. Although visibility was generally poor for most of the flight, 3 medium and 10 small icebergs were sighted south of 52°N in Bonavista and Notre Dame Bays and off Cape Freels. Most of these were grounded and were not considered to present a serious threat to the Grand Banks area unless a sustained period of offshore winds occurred in late May or early June. A total of 20 icebergs were estimated to have crossed 48°N during this month, which is considerably less than the normal of 94. Most of these crossed 48°N while in the Avalon Channel between 52°W and the Newfoundland coast.

June 1975

In early June the only sea ice south of 52°N was very diffuse and rotted ice along the northeast coast of Newfoundland (figure 17). The only ice south of 48°N and east of 51°W that had not yet melted were the remains of a large iceberg first sighted on 14 May and possibly the last of a small iceberg last sighted by Ice Patrol on 23 May. These small bergs and growlers were deteriorating rapidly in an area southeast of the Banks (figure 17). As is typical in the spring, fog and low cloud cover reduced visibility on the Grand Banks to near zero for most of June. Reconnaissance flights on 11 and 12 June averaged less than 30% visual coverage along the tracks flown (figure 18). With the exception of sighting those icebergs scattered along the coast and south of Newfoundland (all west of

51°30′W), no iceberg reports were received in June after the 4th. All ice south of 48°N was calculated to have melted in mid-June, but without visual confirmation that all of the icebergs previously spotted south of Newfoundland had totally disintegrated, the Ice Patrol service continued. Finally a break in the weather occurred on 20 and 21 June. Two flights provided confirmation that no ice existed south of 47°30′N. One small iceberg with growlers had drifted south and grounded off St. John's during the third week of June but it presented no threat to the Grand Banks. With this information and knowledge that the upstream iceberg population was sparse and had little potential of producing a berg that would reach 47°N, notice was given to the maritime community that International Ice Patrol services would be terminated on 23 June. The Ice Patrol Reconnaissance Detachment returned to the United States on that date. It was estimated that a total of 5 icebergs crossed 48°N during June.

July-August

No more icebergs were known to have drifted south of 48°N during July or August. The total count of icebergs crossing 48°N for 1975 was 101. Although a number of sightings continued to be reported to the Ice Patrol during the summer, most were located just east of the Strait of Belle Isle. One exception was a group of bergs sighted between 48°34′N–48°49′N and 48°33′W–49°05′W. These were resighted again slightly further south on 8 August. In July only belts and strips of sea ice existed off the Labrador coast and the only concentrated pack was off Baffin Island between 62°N and 72°N. By mid-August, this entire area was free of sea ice.

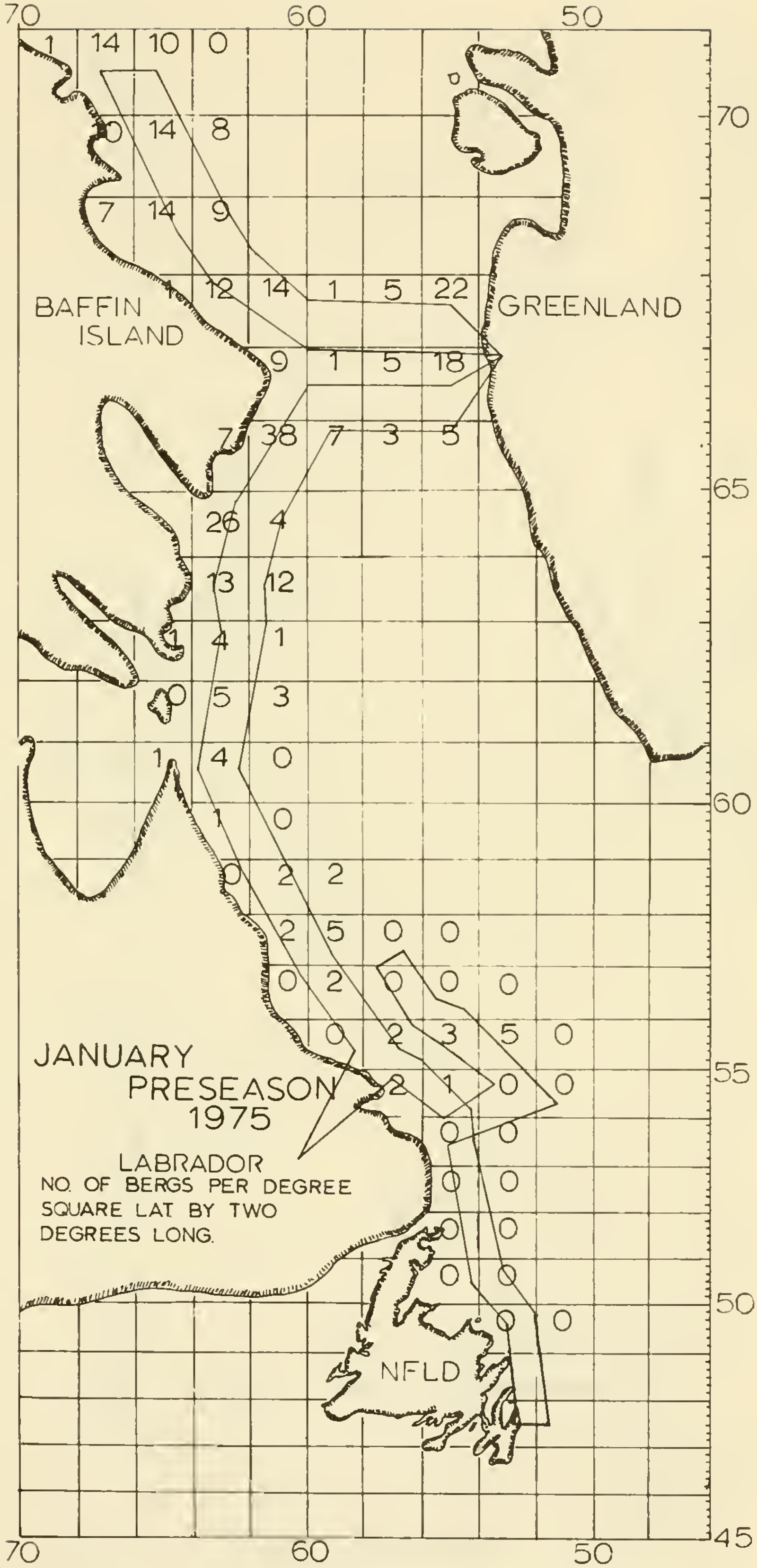

FIGURE 1.—Preseason Iceberg Survey 20–28 January 1975

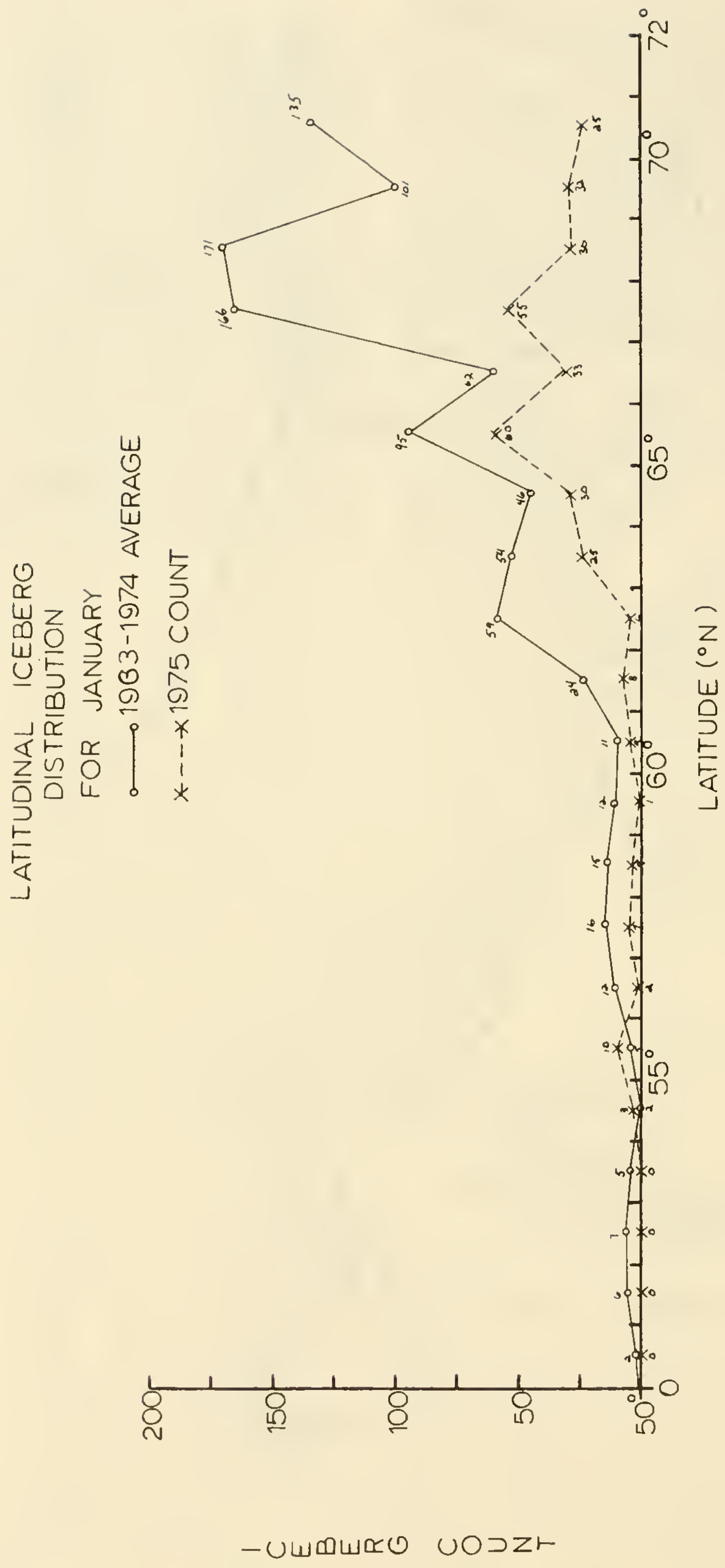

FIGURE 2.—Latitudinal Iceberg Distribution, JANUARY PRESEASON FLIGHTS

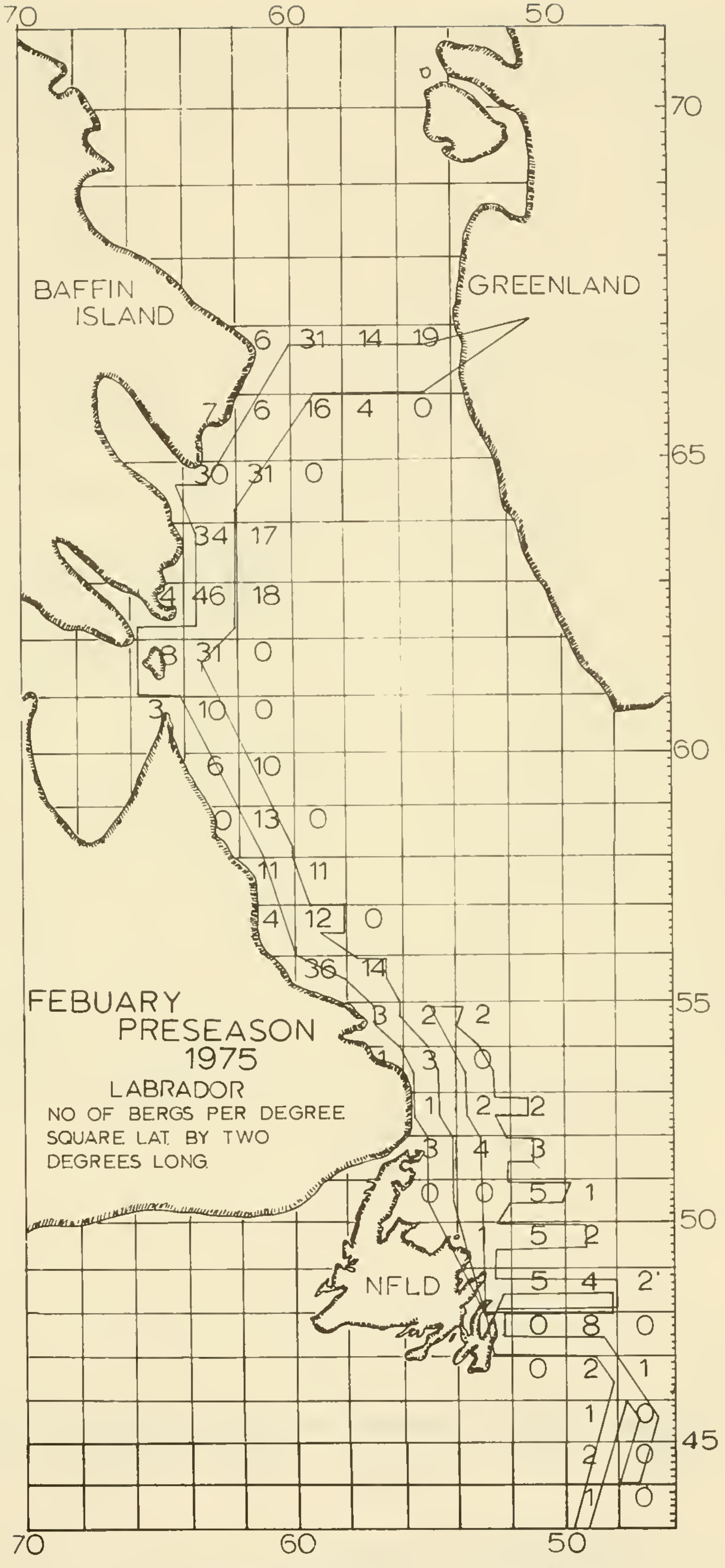

FIGURE 3.—Preseason Iceberg Survey 24 Feb–12 March 1975

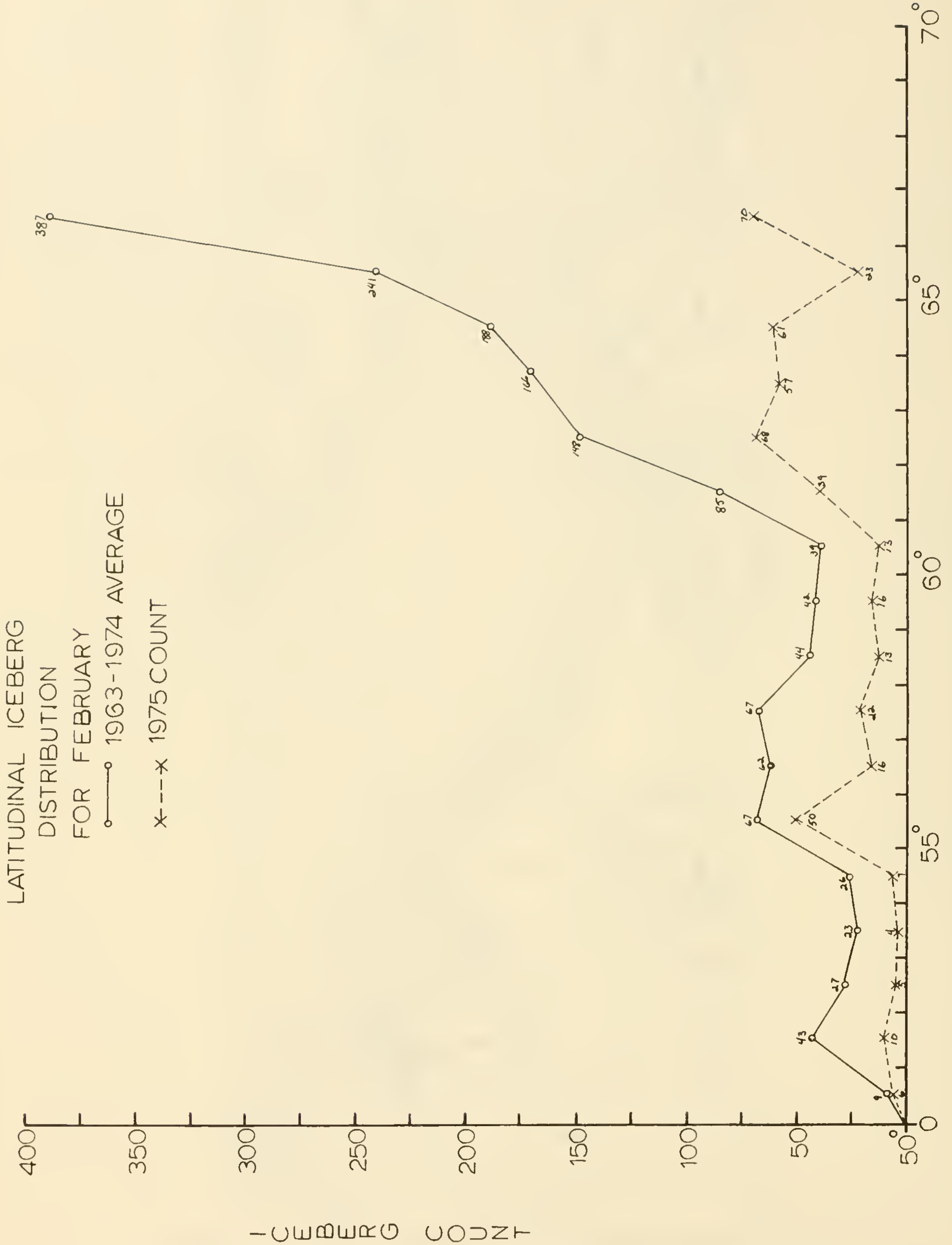

FIGURE 4.—Latitudinal Iceberg Distribution, FEBRUARY PRESEASON FLIGHTS

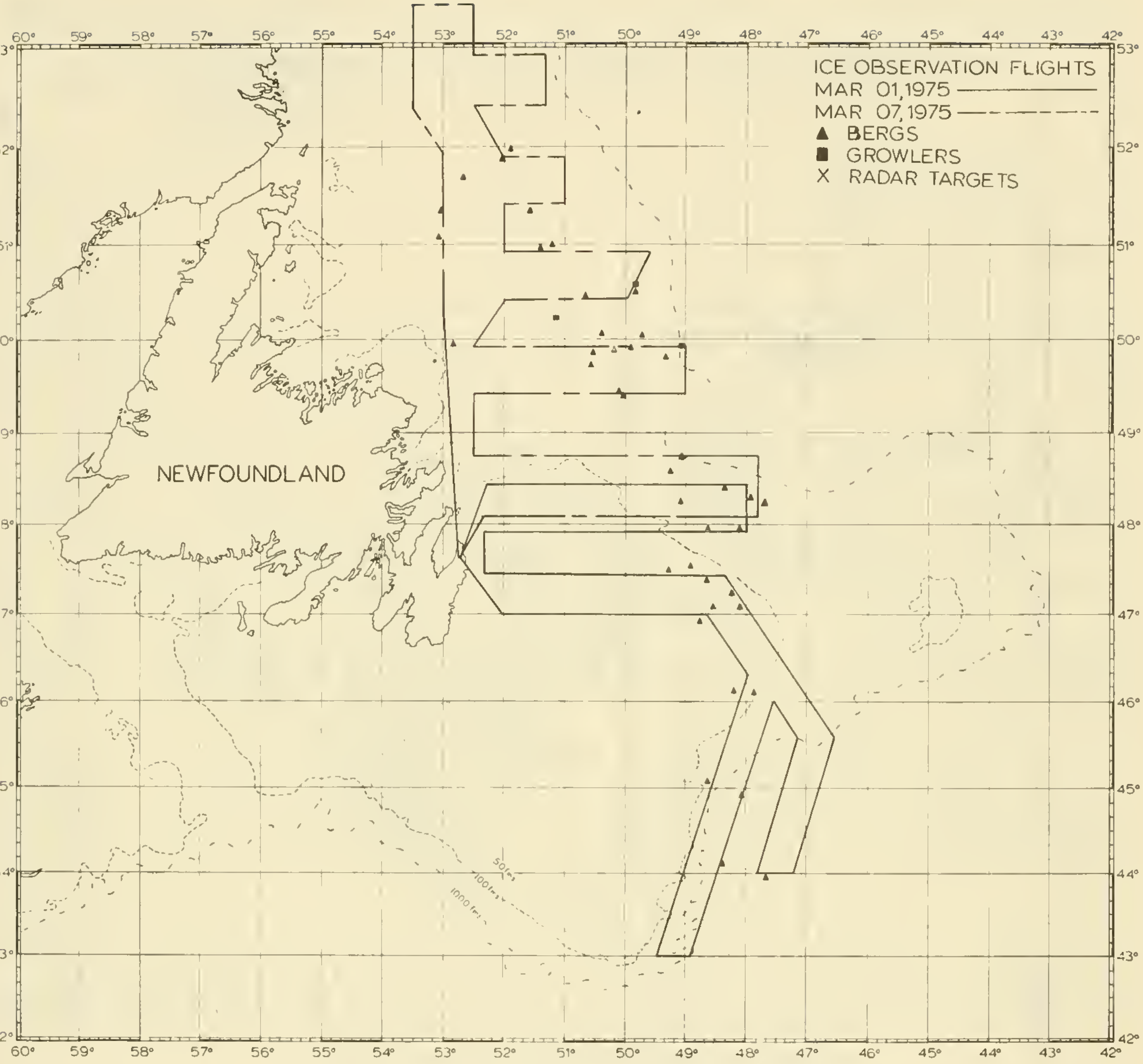

FIGURE 5.—Ice Observation Flights 1 and 7 March 1975

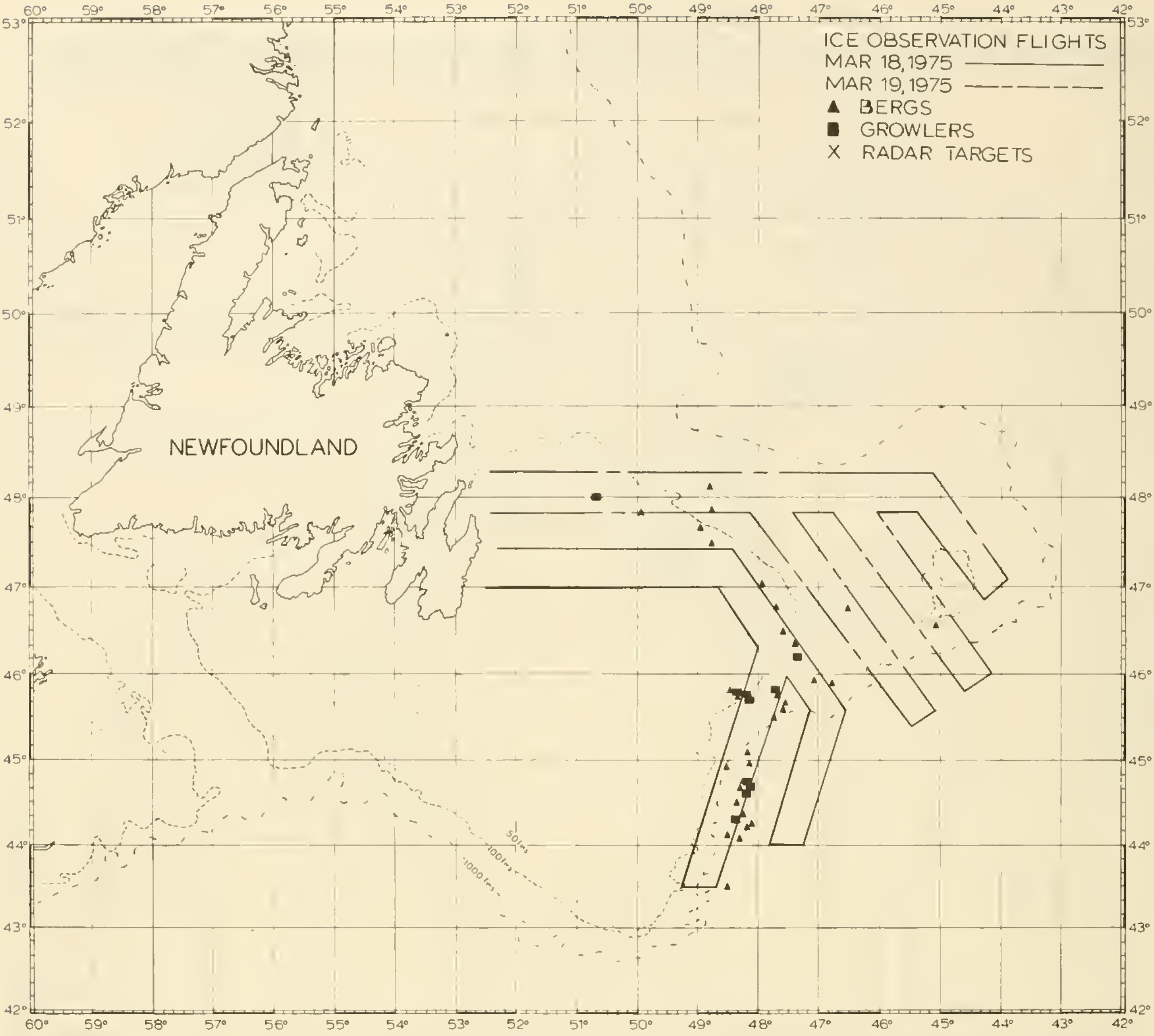

FIGURE 6.—Ice Observation Flights 18 and 19 March 1975

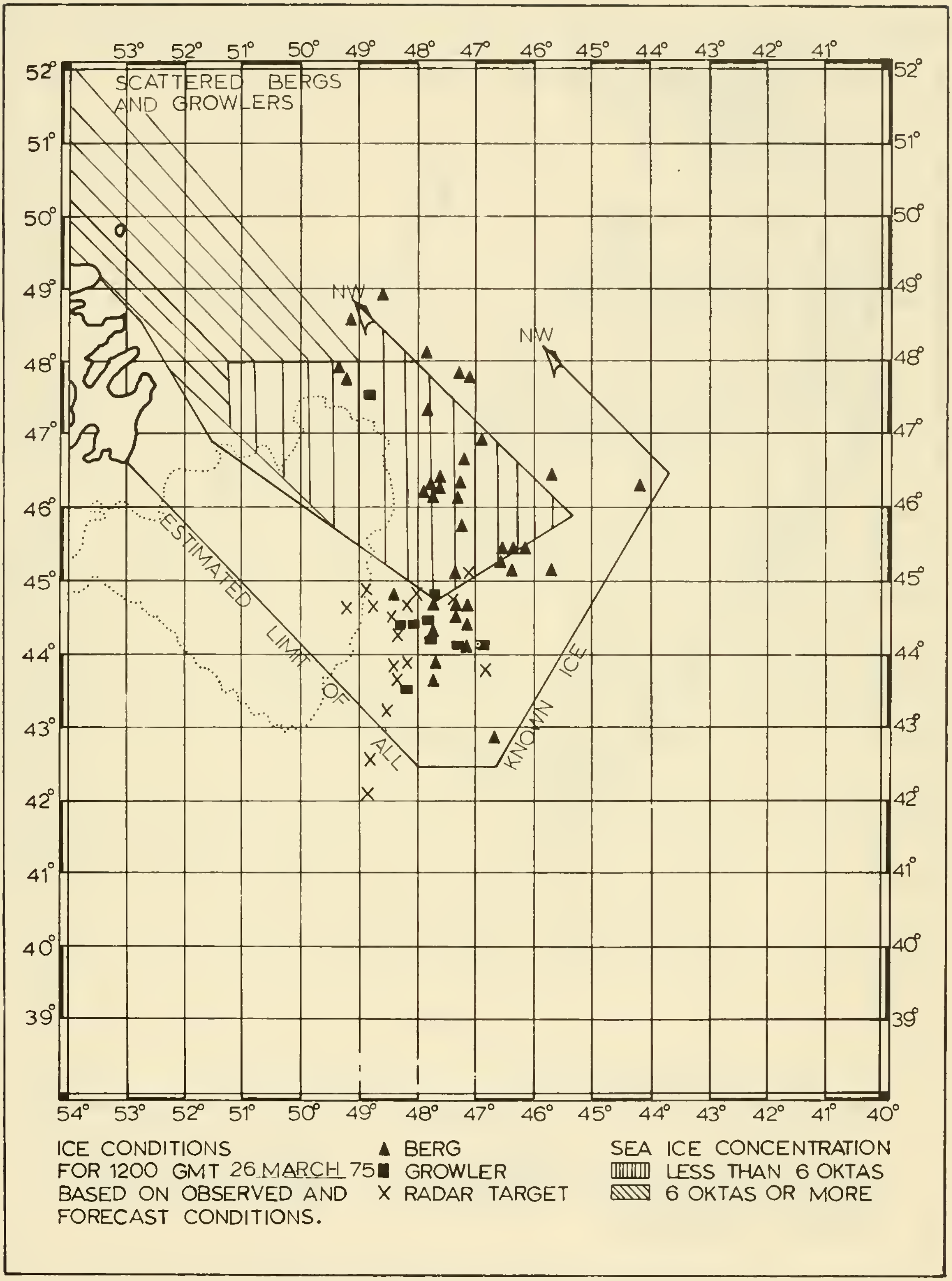

FIGURE 7.—Ice Conditions, 1200 GMT 26 March 1975

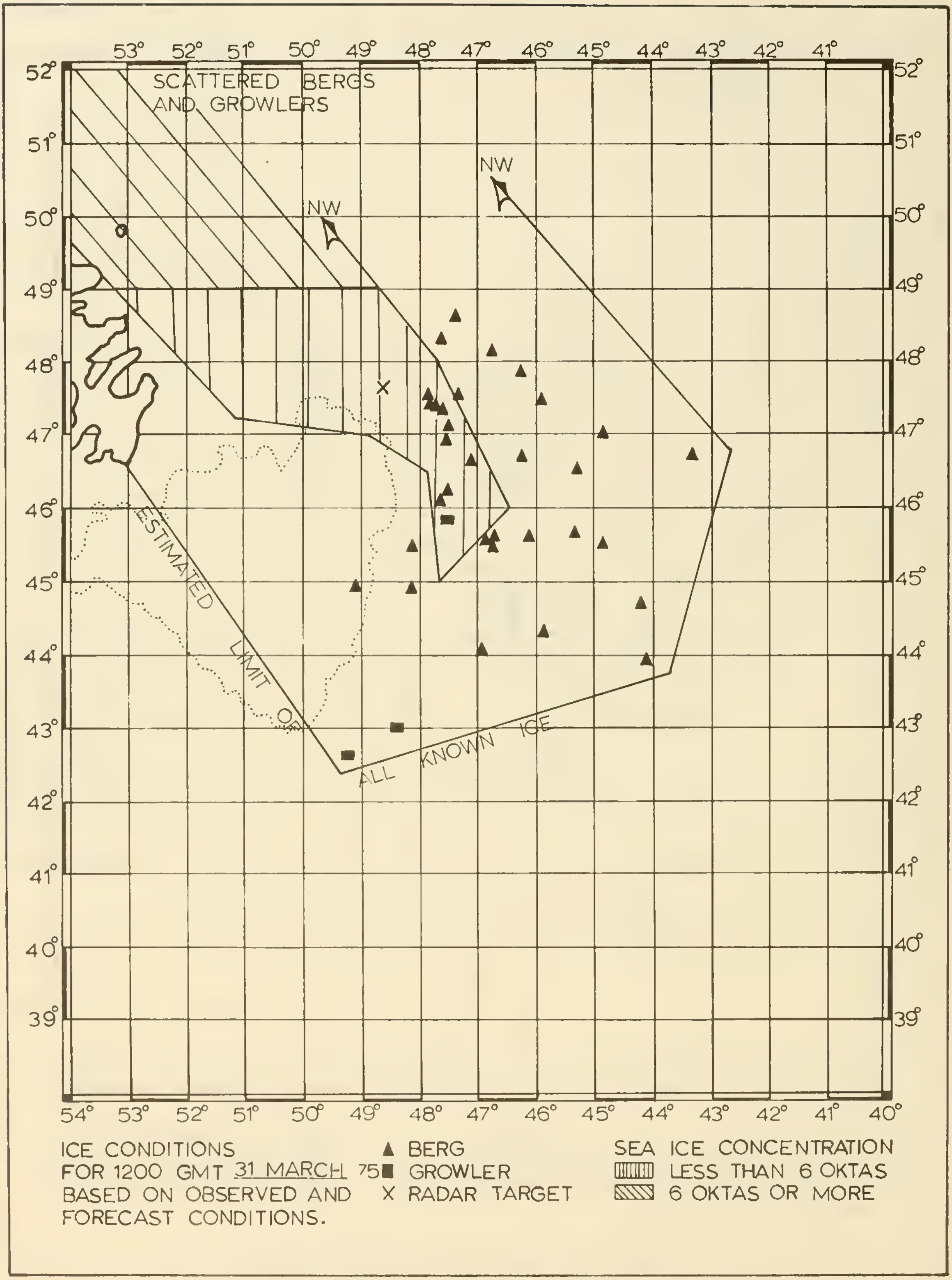

FIGURE 8.—Ice Conditions, 1200 GMT 31 March 1975

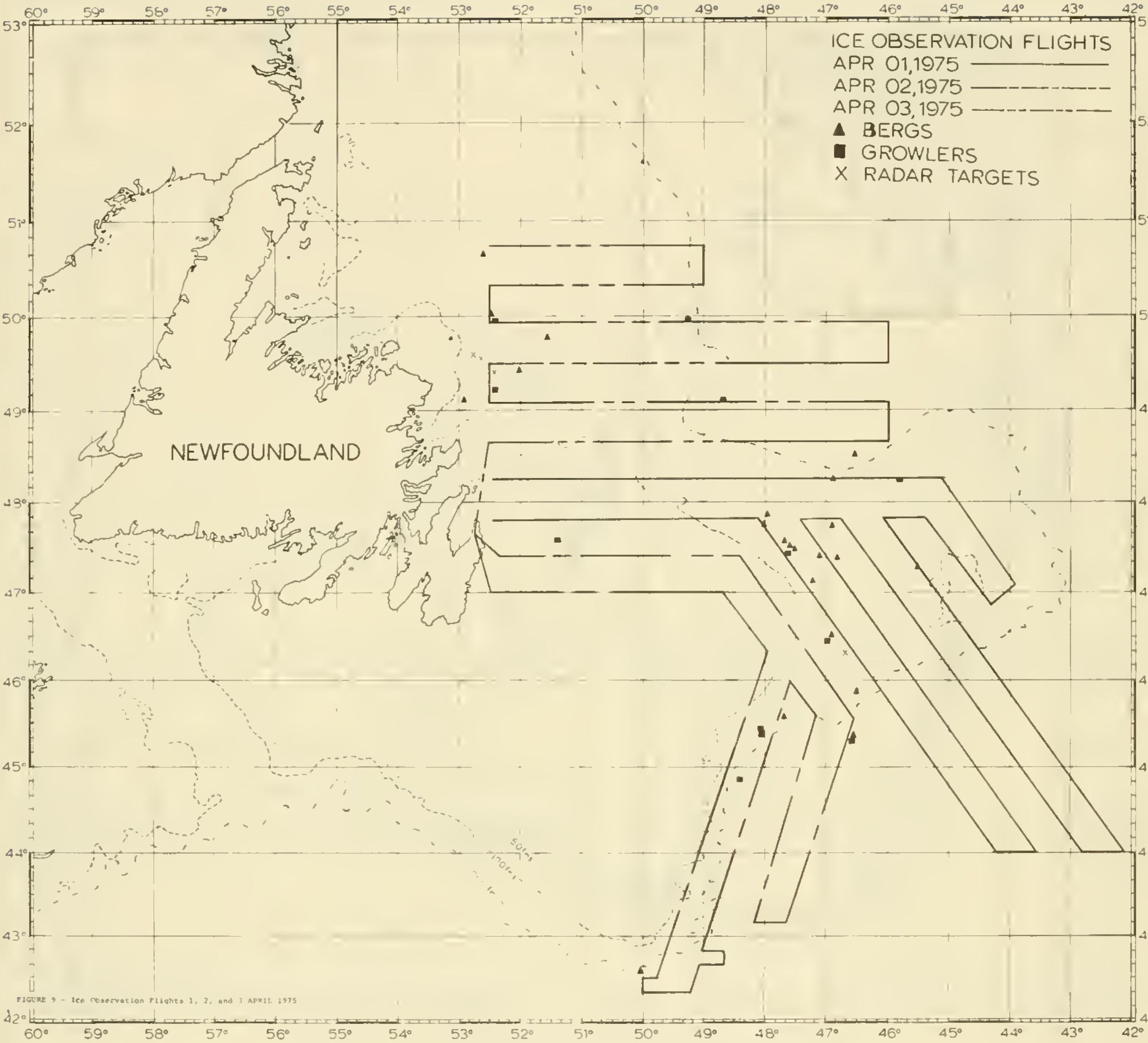

FIGURE 9.—Ice Observation Flights 1, 2, and 3 April 1975

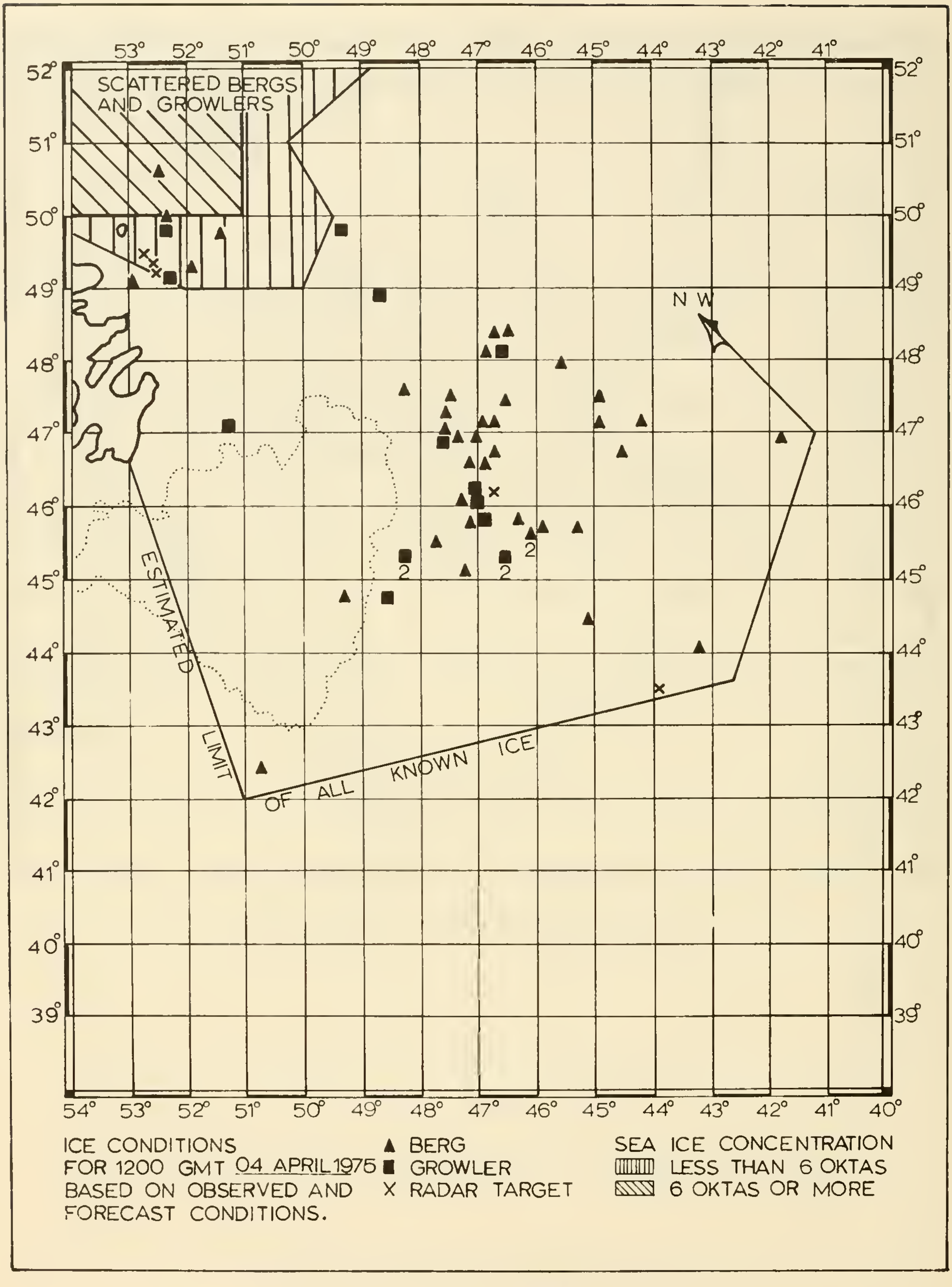

FIGURE 10.—Ice Conditions, 1200 GMT 4 April 1975

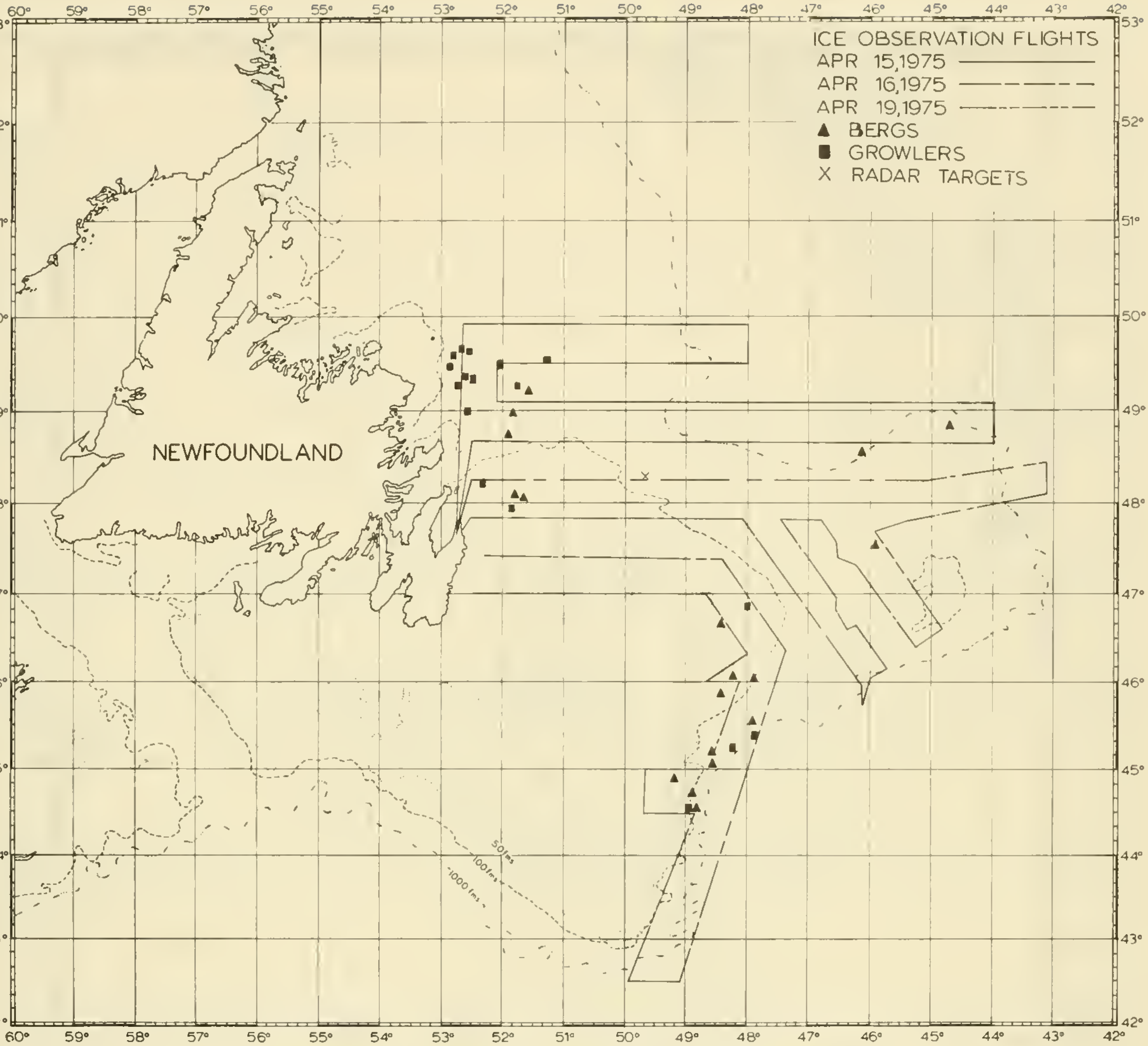

FIGURE 11.—Ice Observation Flights 15, 16, and 19 April 1975

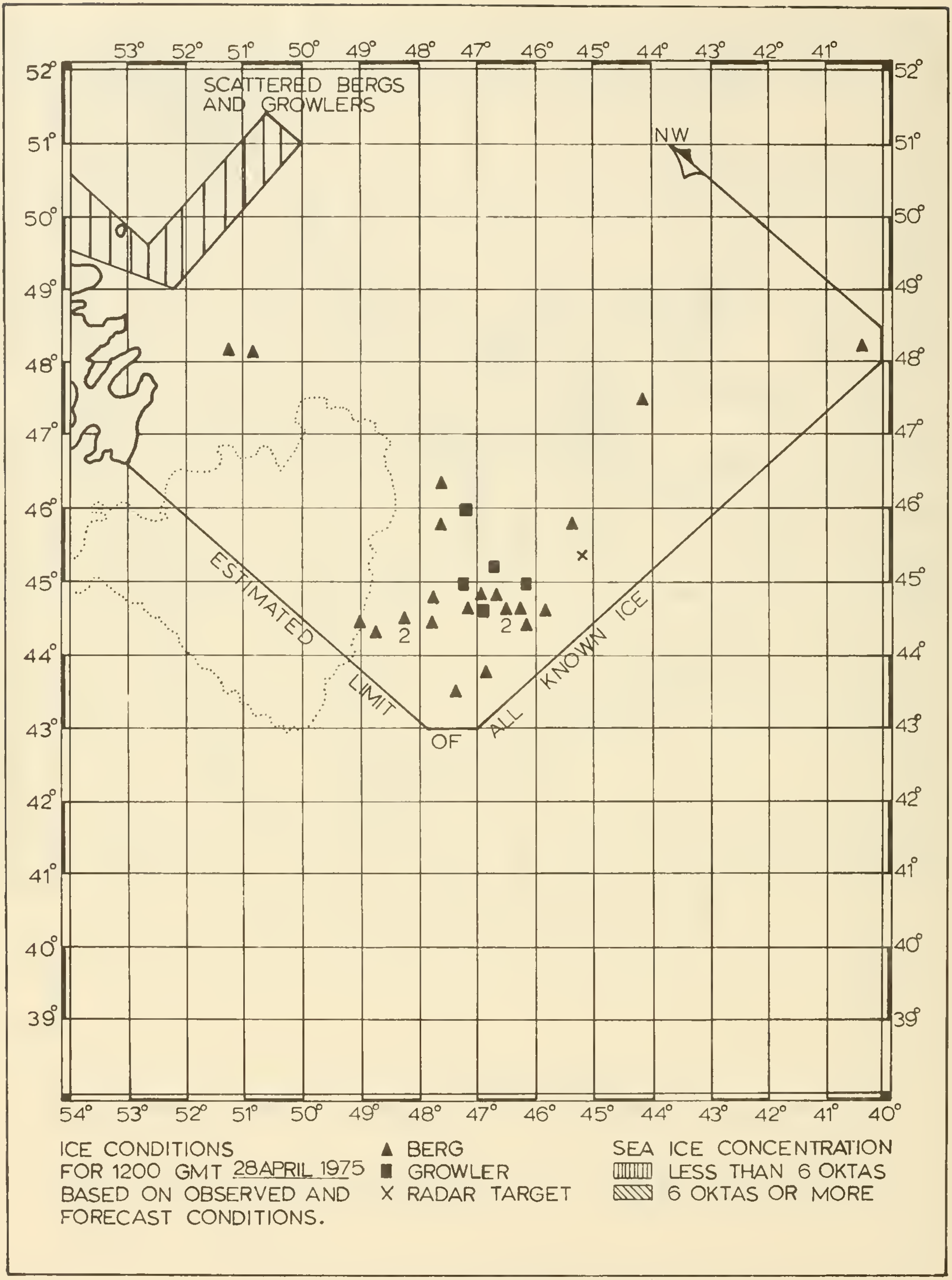

FIGURE 12.—Ice Conditions, 1200 GMT 28 April 1975

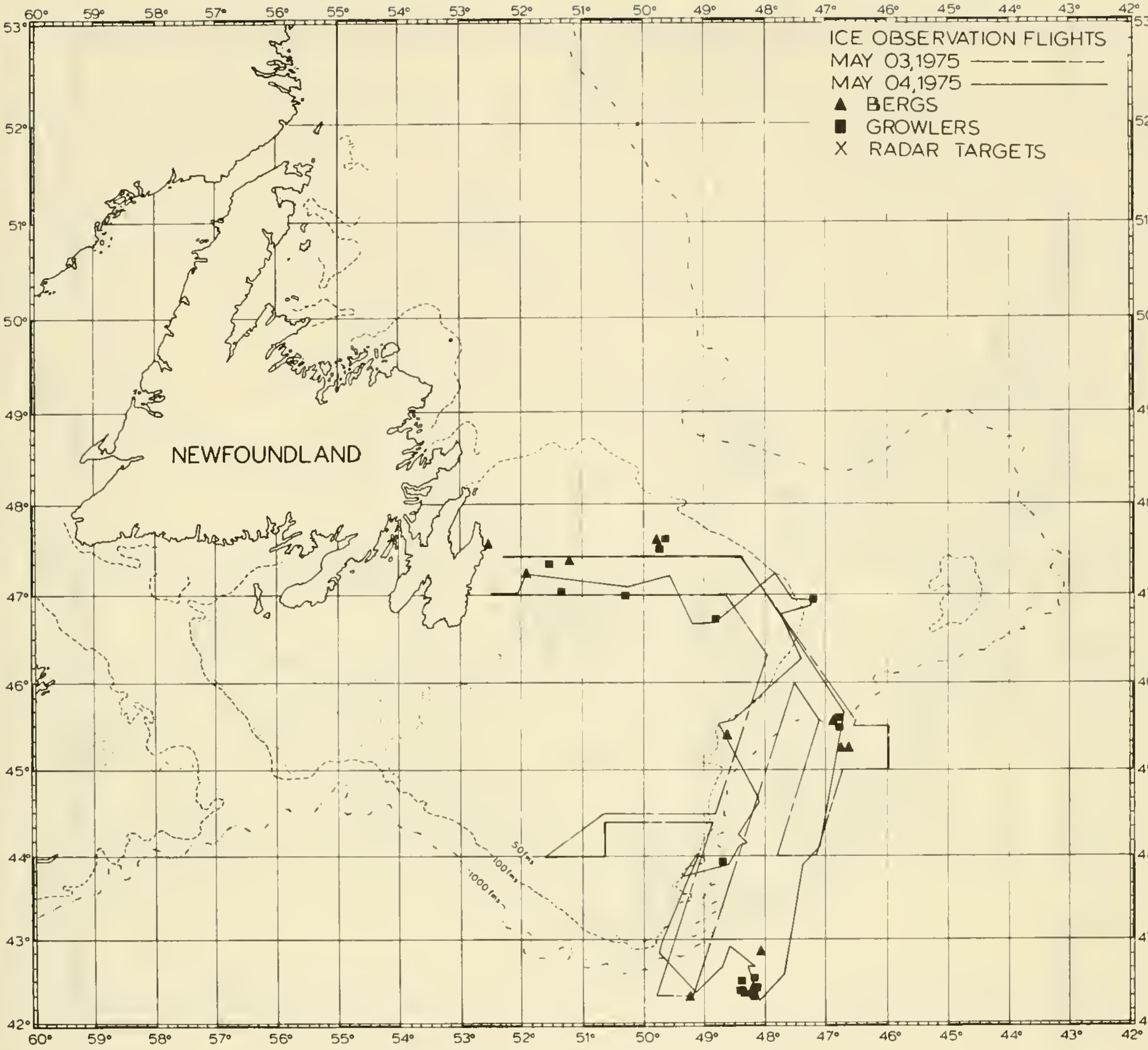

FIGURE 13.—Ice Observation Flights 3 and 4 May 1975

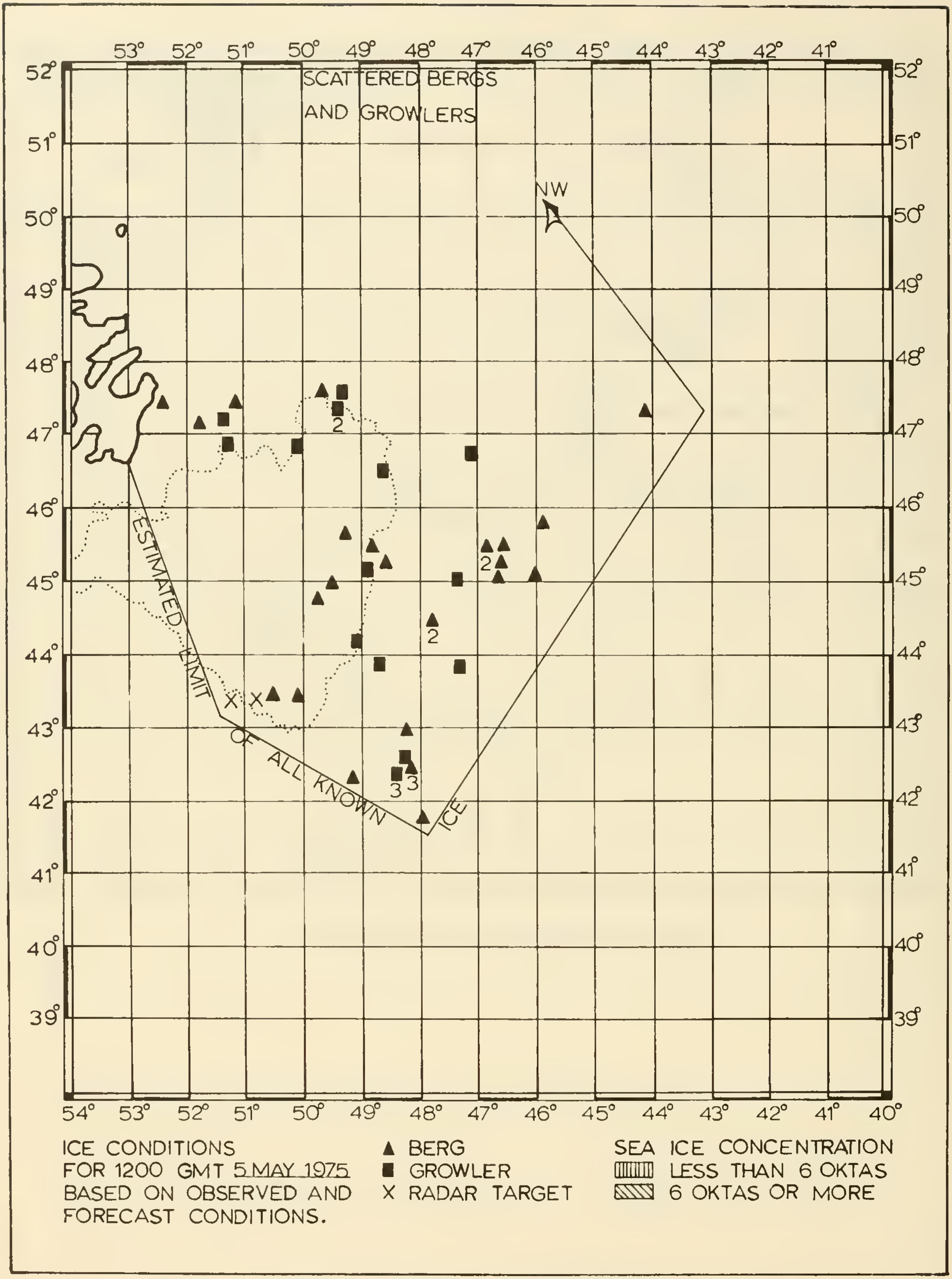

FIGURE 14.—Ice Conditions, 1200 GMT 5 May 1975

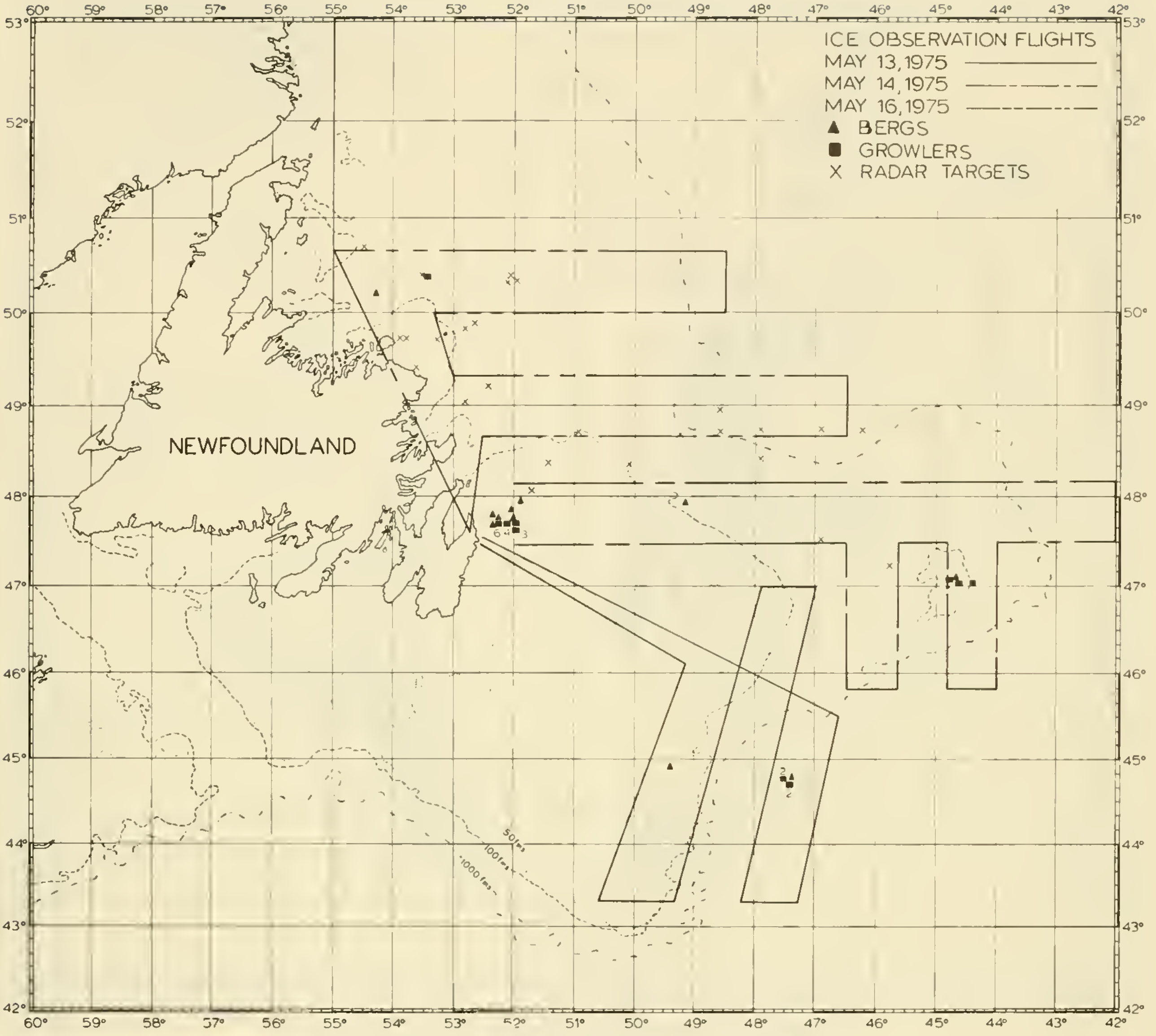

FIGURE 15.—Ice Observation Flights 13, 14, and 16 May 1975

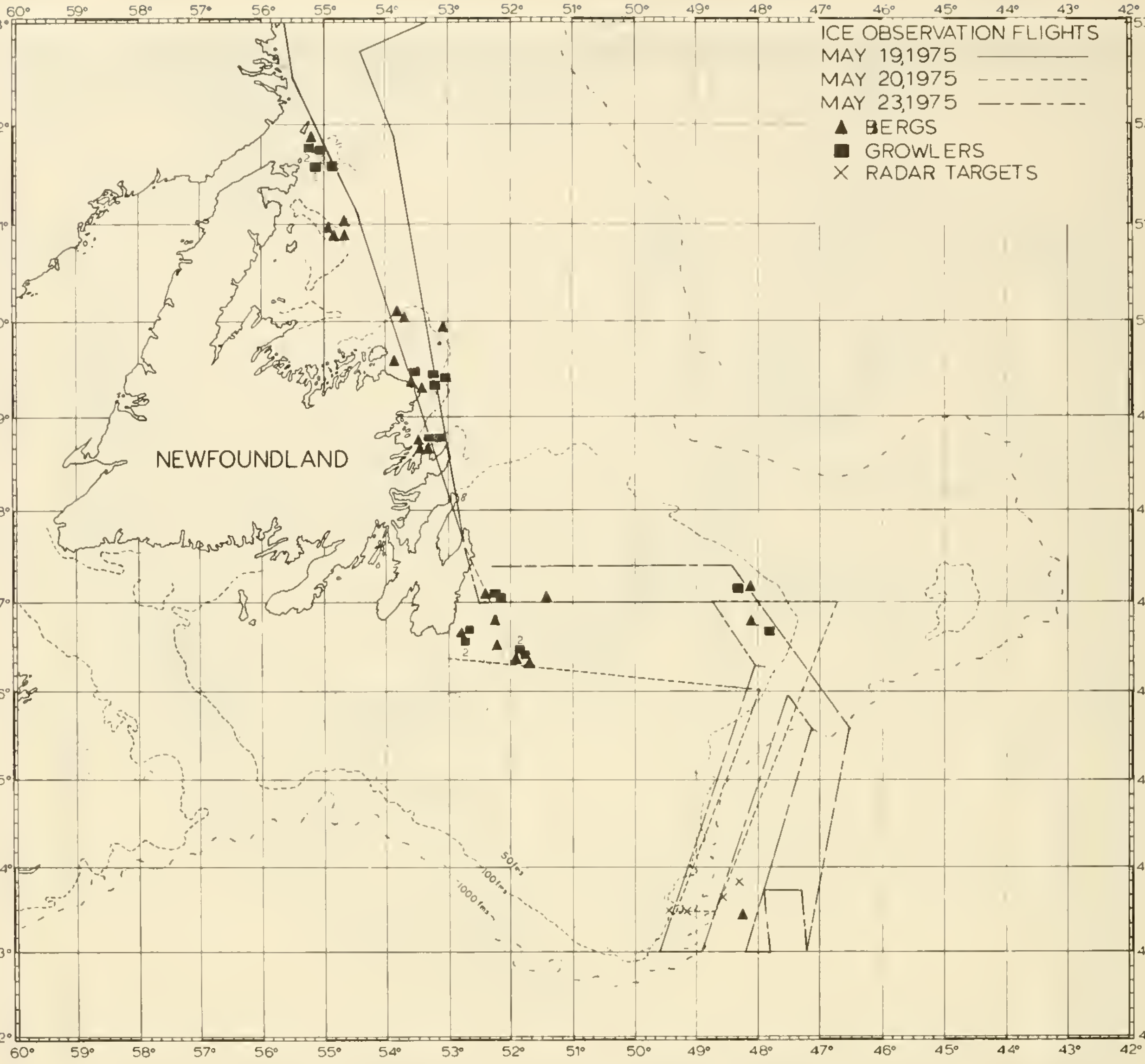

FIGURE 16.—Ice Observation Flights 19 and 23 May 1975

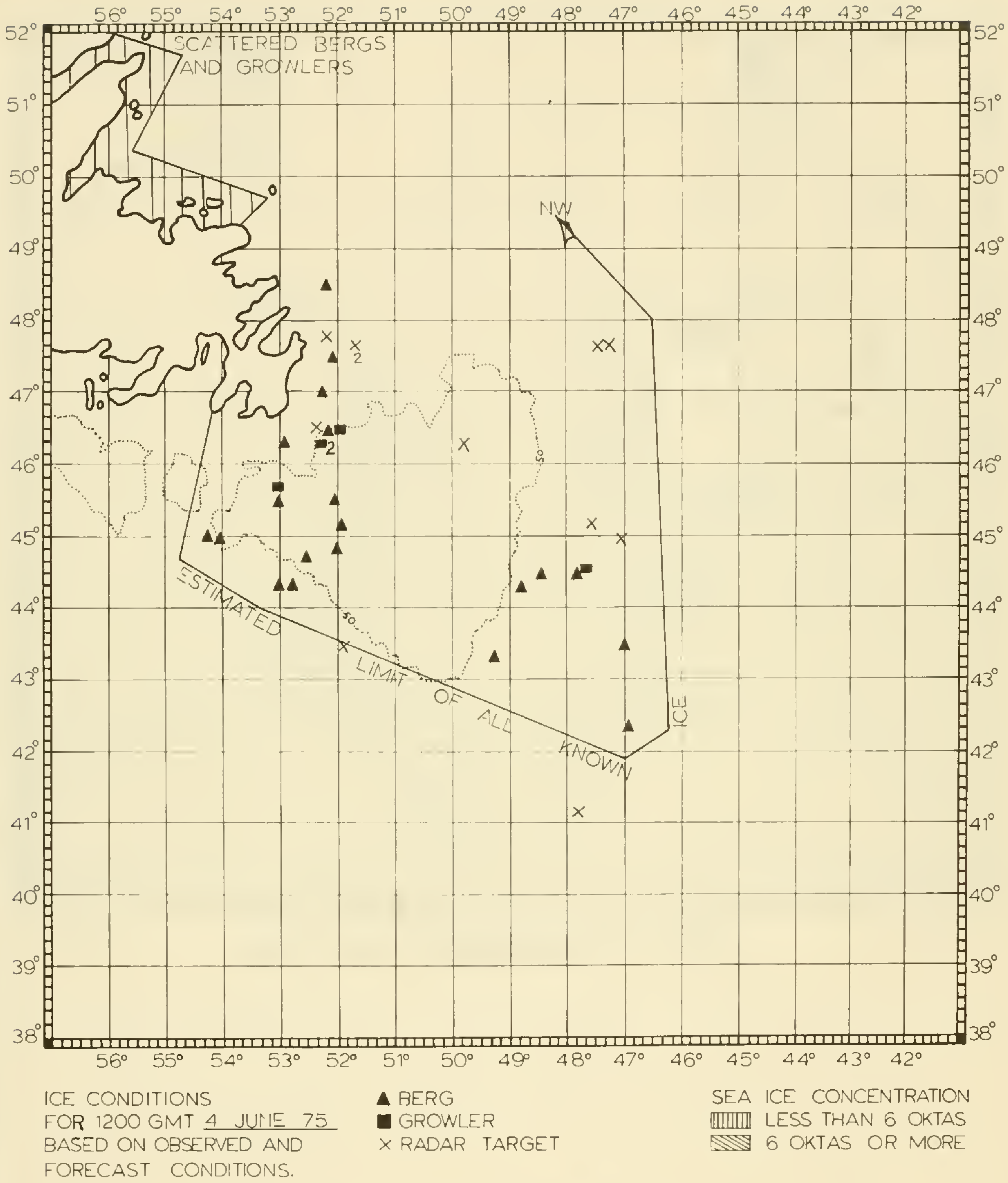

FIGURE 17.—Ice Conditions, 1200 GMT 4 June 1975

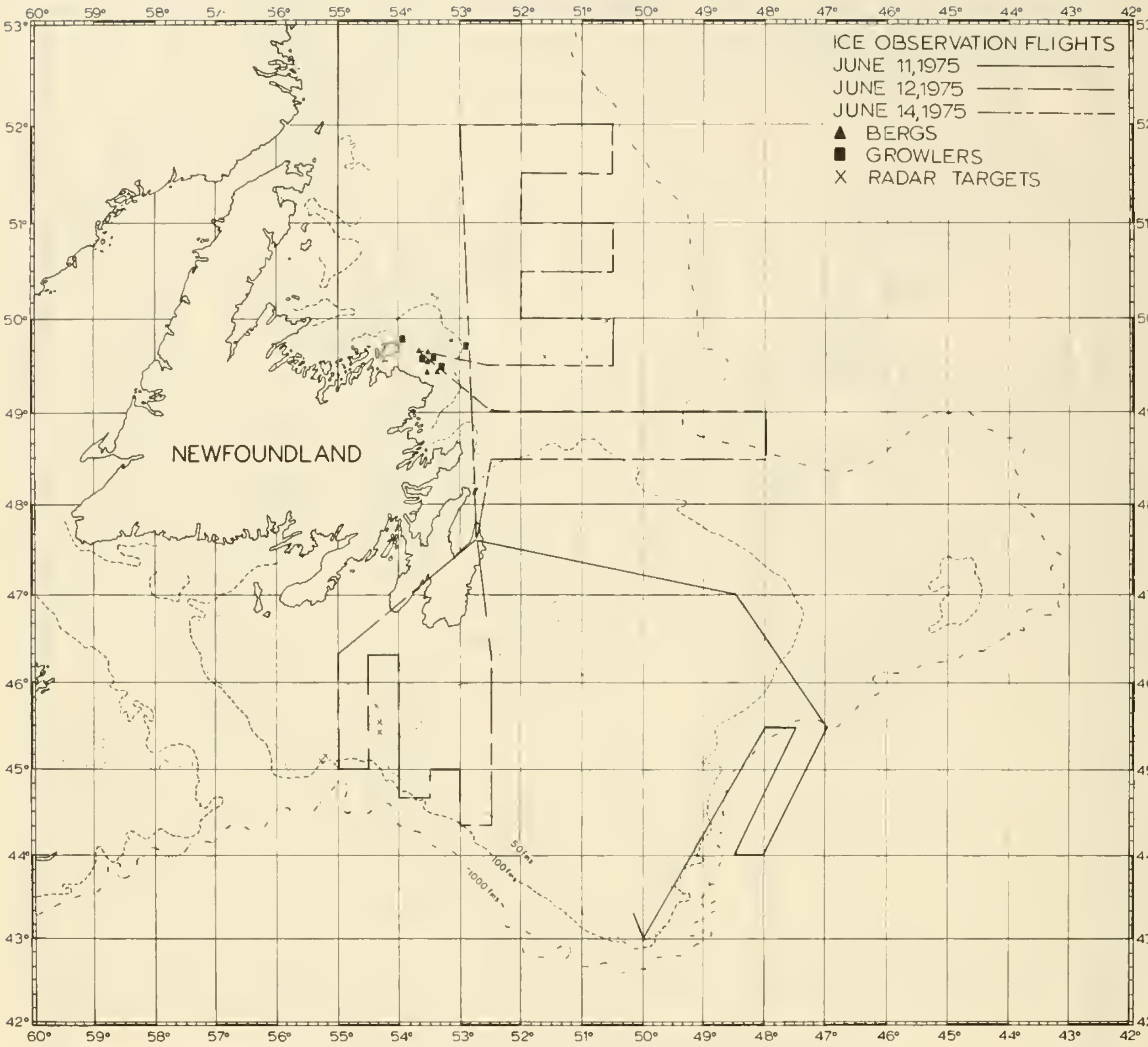

FIGURE 18.—Ice Observation Flights 11, 12, and 14 June 1975

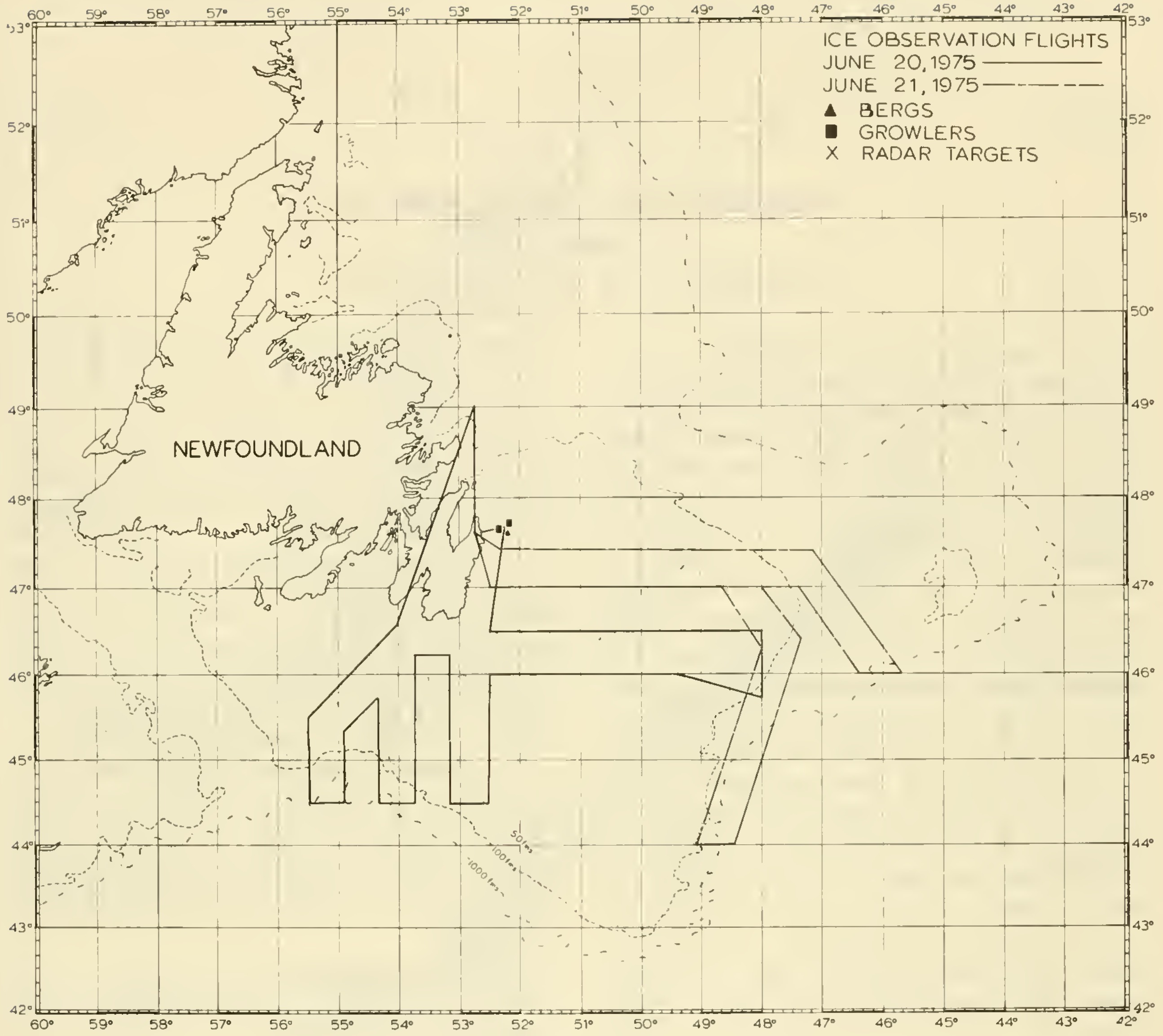

FIGURE 19.—Ice Observation Flights 20 and 21 June 1975

OCEANOGRAPHIC CONDITIONS, 1975

D. G. MOUNTAIN

(U.S Coast Guard Oceanographic Unit)

Two oceanographic cruises during the periods 2–29 April and 20 May to 10 July were conducted in support of the International Ice Patrol aboard the USCGC EVERGREEN (WAGO–295). Temperature and salinity data were taken to a depth of at least 1000 meters, or near bottom in shallower water, using a S/T/D Environmental Profiling System. The data were recorded on magnetic tape using a digital data logger, and were processed at sea to yield dynamic height values relative to the 1000 decibar surface. Five separate surveys were completed to yield nearly synoptic dynamic topography (Figures 20 to 24).

The dynamic topography for the first survey in April (Figure 20) shows the Labrador Current flowing southward along the eastern edge of the Grand Banks and the North Atlantic Current flowing northeastward further to the east. This situation is similar to that normally observed. However, between the two currents a large anticyclonic (clockwise) eddy is also indicated. The eddy likely was shed from the North Atlantic Current. The second survey in April (Figure 21) suggests that the eddy moved southward and rejoined the North Atlantic Current.

During the second cruise two surveys with close station spacings (Figures 22 and 24) were conducted for use in verifying a numerical model of the currents and water properties in the area developed by Captain R. C. KOLLMEYER. The Labrador Current changed little from the earlier observations, while the North Atlantic Current entered the survey area from the southeast then turned clockwise to exit to the northeast. The observations between these surveys (Figure 23) suggests that the turning of the current was part of a meander like feature.

The maximum current in the Labrador Current calculated from the dynamic topography ranged from 28 to 65 cm/sec at different sections, while the volume transport ranged from 0.77 to 7.40, x10^6m^3/sec. In the North Atlantic Current maximum calculated velocities ranged from 45 to 75 cm/sec.

A more complete analysis of this data will be published in the U.S. Coast Guard Oceanographic Report Series (CG–373).

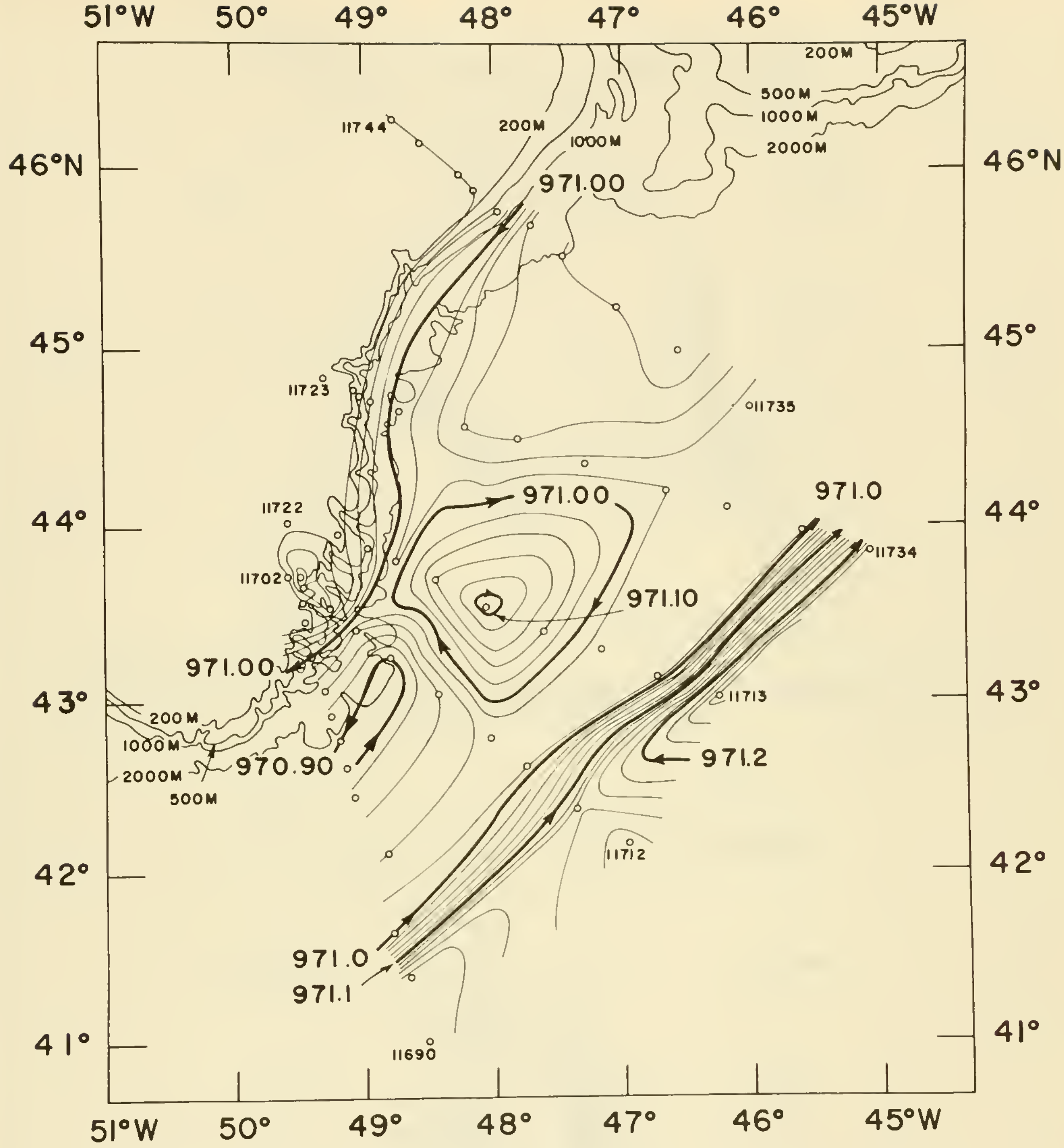

FIGURE 20.—Dynamic Topography of the Sea Surface with Reference to the 1000 Decibar Surface First Cruise, April 4–15, 1975

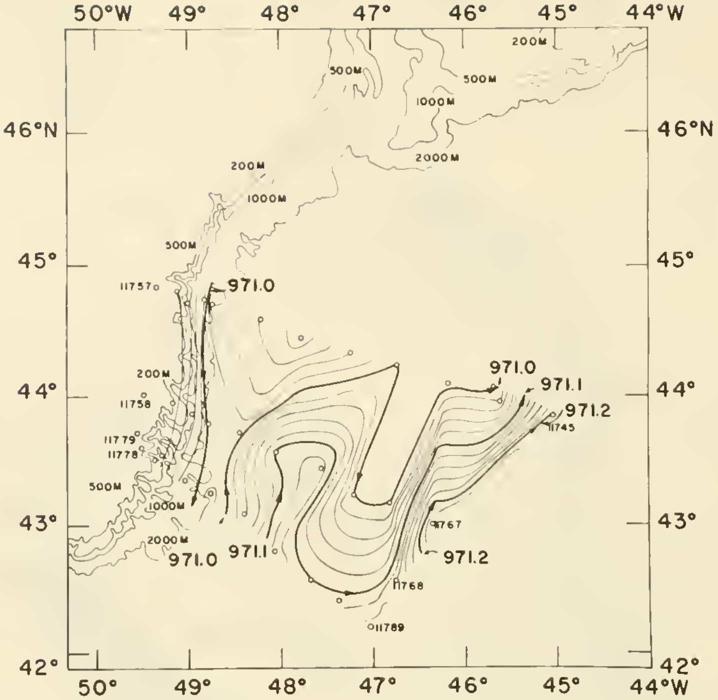

FIGURE 21.—Dynamic Topography of the Sea Surface with Reference to the 1000 Decibar Surface First Cruise, April 21–25, 1975

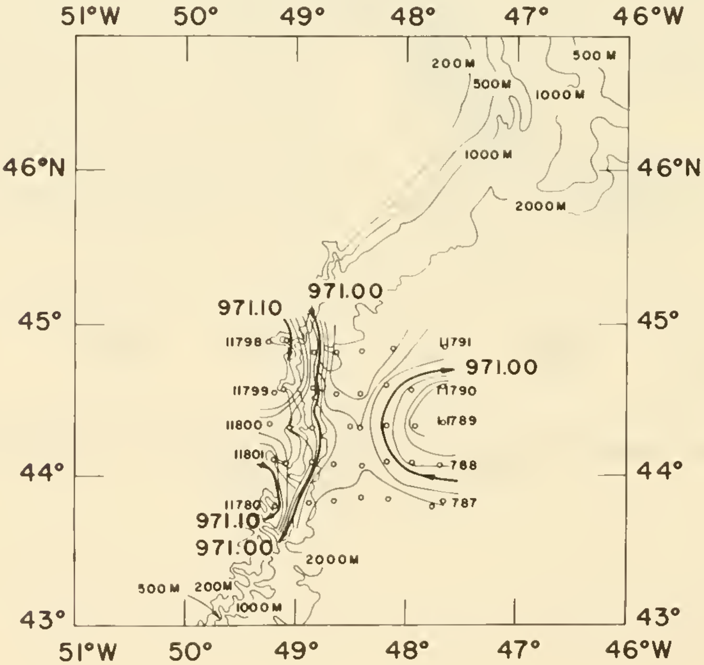

FIGURE 22.—Dynamic Topography of the Sea Surface with Reference to the 1000 Decibar Surface Second Cruise, May 26–27, 1975

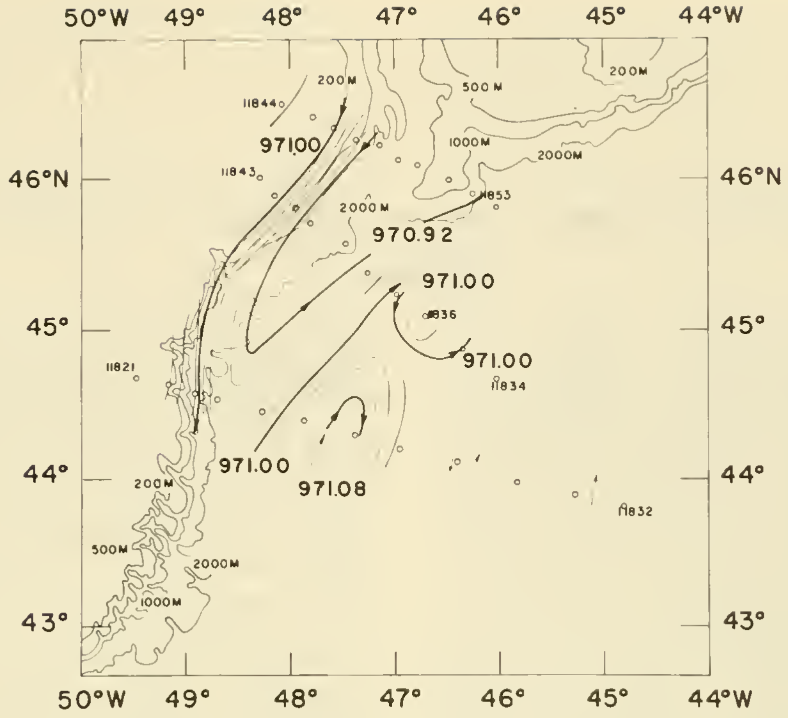

FIGURE 23.—Dynamic Topography of the Sea Surface with Reference to the 1000 Decibar Surface Second Cruise, May 29 thru June 1, 1975

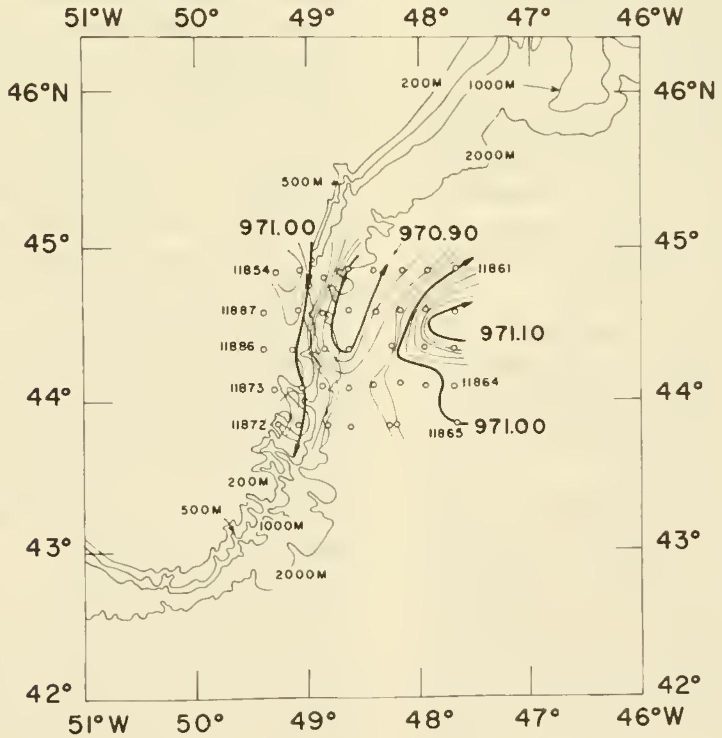

FIGURE 24.—Dynamic Topography of the Sea Surface with Reference to the 1000 Decibar Surface Second Cruise, June 3-6, 1975

DISCUSSION OF ICEBERG AND ENVIRONMENTAL CONDITIONS

1975 Season

Despite annual fluctuations in iceberg productivity of the Greenland glaciers, sufficient bergs are normally available in the west Greenland inventory to produce a record iceberg year on the Grand Banks, given the right environmental conditions. Four factors or conditions primarily determine the number of icebergs that will drift toward and ultimately survive to reach the Grand Banks. These are the intensity or volume transport rate of the Labrador Current; the direction, magnitude and duration of the prevailing winds encountered by the icebergs during this drift; the extent of the sea ice cover available to protect the icebergs; and, finally, the environmental conditions to which the iceberg is exposed when out of sea ice (i.e., air and water temperatures, wave action). Abnormalities in any of these could be responsible for either a very light or heavy iceberg season off Newfoundland.

The 1975 iceberg season saw only 101 icebergs cross 48°N latitude. This was less than one third of the 1946 to 1974 average. Why did so few icebergs reach the Grand Banks during 1975? The following paragraphs provide a discussion of the 1975 iceberg and environmental conditions in an attempt to answer this question.

This season's sea ice cover is discussed in the Ice Conditions section. Features of the Labrador and North Atlantic Current observed during 1975 are reviewed in the Oceanographic Conditions section of this publication.

The first indication that the season would probably be lighter than normal came with the January preseason mission. During these flights, only 336 icebergs were sighted, one third the 1963–1974 average (See Figure 2). During the February preseason flights, 518 icebergs were observed south of 67°N latitude. This was again about one third the average, but only one quarter the number normally encountered between 62°N and 67°N latitude during late February (See Figure 4). The track lines for both of these surveys were selected to cover those areas where the larger icebergs, under the influence of favorable environmental conditions, would be in a position to reach the Grand Banks. The low numbers of icebergs encountered during these surveys were believed to be due primarily to two conditions. First, Baffin Bay was essentially free of sea ice for most of two months and the west coast of Greenland south of 75°N was free of sea ice from mid-July until early November. This was some two or three weeks longer than normal, during which time the icebergs were exposed to open water. Secondly, a deeper than normal Icelandic low during the late fall created higher winds and thus more turbulent seas off the middle west Greenland coast. These factors combined to accelerate the deterioration rate of icebergs in this area. Certainly, the fact that the last three seasons had brought record numbers of icebergs to the Grand Banks had some effect on the icebergs in a position to drift south during 1975. Although, as always, large numbers of icebergs were available in the west Greenland inventory, it is believed that fewer were near or in the primary ocean currents carrying icebergs on their long trek to the Grand Banks.

Figures 25a through 25e show the normal and 1975 surface pressure patterns for November through August. The isobars, shown as heavy solid lines in these figures, provide an indication of average wind direction in any particular area. Winds tend to blow in a direction nearly parallel to the isobars, counterclockwise around a low pressure area and clockwise around a high for the Northern Hemisphere.

The predominant characteristics of the average pressure patterns from November through March was the abnormally intense Icelandic low producing stronger than normal northerly and northwesterly winds south of Davis Strait along the Baffin Island and Labrador coasts. The resultant flow brought the icebergs south much faster than

normal. This was particulary true during February when the Icelandic low averaged some 17 mbs below normal.

From the extremes of February, the pressure patterns returned to near normal in March with the Icelandic low somewhat deeper and just slightly west of its normal position. This pattern produced winds more on-shore than experienced earlier in the season. April saw an intensification of this on-shore flow off Labrador as the Icelandic low spread to a broad trough extending from just southwest of Iceland to the United States' Northeast. A high dominated the Hudson Bay area at this time. These on-shore winds drove many of the icebergs aground off Labrador.

This was the primary reason that so few icebergs drifted south of 48°N during the latter part of the 1975 season.

During May, the Icelandic low appeared as a more intense feature and shifted to a position more south and west than normal. This produced northerly winds close to the Newfoundland coast and brought some icebergs south through the Avalon Channel.

As was normal, winds averaged on-shore for the remainder of the season, inhibiting any further iceberg intrusion onto the Grand Banks.

Surface pressure gradients (differences in atmospheric pressure along a geographically oriented line) provide an indication of wind velocities that exist in the area. The steeper the gradients or more rapid the pressure change, the higher the wind speed will be. In an attempt to understand the magnitude and primary direction of winds along the main drift routes of the icebergs heading toward the Grand Banks, six such gradients have been defined by the Ice Patrol for Davis Strait and off the Newfoundland and Labrador coasts. (See Figure 21). From an analysis of these gradients, inferences can be made as to the northwesterly winds producing southerly iceberg drift, accentuating the Labrador Current, reducing the air and sea temperatures, and spreading and developing sea ice along the coasts of Labrador and Newfoundland.

Gradients assigned numbers 1 and 2 in figure 26 measure the winds off the coast of Labrador which are important in setting up the drift for transporting icebergs to the general area northeast of Newfoundland. Gradient 3 measures the wind component which assists or impedes icebergs as they drift south along the eastern slope of the Grand Banks. Gradient 4 is a measurement of the influence of westerly (or easterly) winds along the northern slope of the Grand Banks. This is important in determining iceberg drift away from (or toward) the Newfoundland coast and into (or out of) the core of the Labrador Current. If the westerly winds are too strong or persistent when the bergs reach the northeast corner of the Grand Banks, they may be carried out over Flemish Cap and deteriorate rapidly as they are pushed into the warmer waters of the North Atlantic Current. Gradients 5 and 6 provide a preseason indication of probable icebreg drifts south and west in Davis Strait.

The 1975 pressure gradient data are shown graphically in figures 27 and 28 with a comparison provided to their 1946–1974 normals. The most obvious and significant features in these gradients are the high peaks that occurred in gradients 1, 2 and 3 during January and February. These peaks indicate a much stronger than normal southeasterly wind drift accounting for the relatively large numbers of icebergs reaching the Grand Banks early in the season. Likewise, northerly flow and below normal southerly flow indicated in gradients 3 and 2 respectively during March and April help to explain the decreased influx of icebergs during the early spring. South winds across gradient 3 during this period also brought warm air into the area accounting for the retreat of the sea ice in late March and April as discussed earlier in the Ice Conditions section. Slightly above normal easterly flows early in the season, as indicated through gradient 4, kept the icebergs offshore during this period.

Air temperatures over Labrador and east Newfoundland waters were predominately 1° to 6°F below normal throughout the ice season. The exception was February, when temperatures averaged 6° to 13°F below normal. This month was recorded as the coldest on record east of Newfoundland. Graphic presentations of cumulative frost degree days and melting degree days are provided in figures 29 and 30 for selected shore stations along Canada's east coast. The locations of these stations are shown in figure 26. A frost degree day is defined as one day mean temperature of one Fahrenheit degree below 32°

(e.g., one day at 20°F would equal 12 frost degree days). Similarly, a melting degree day is one day mean temperature of one Fahrenheit degree above 32°. All stations had greater than normal accumulations of frost degree days during 1975, but also, with the exception of Hopedale, had a near normal or above normal accumulation of melting degree days by the end of July.

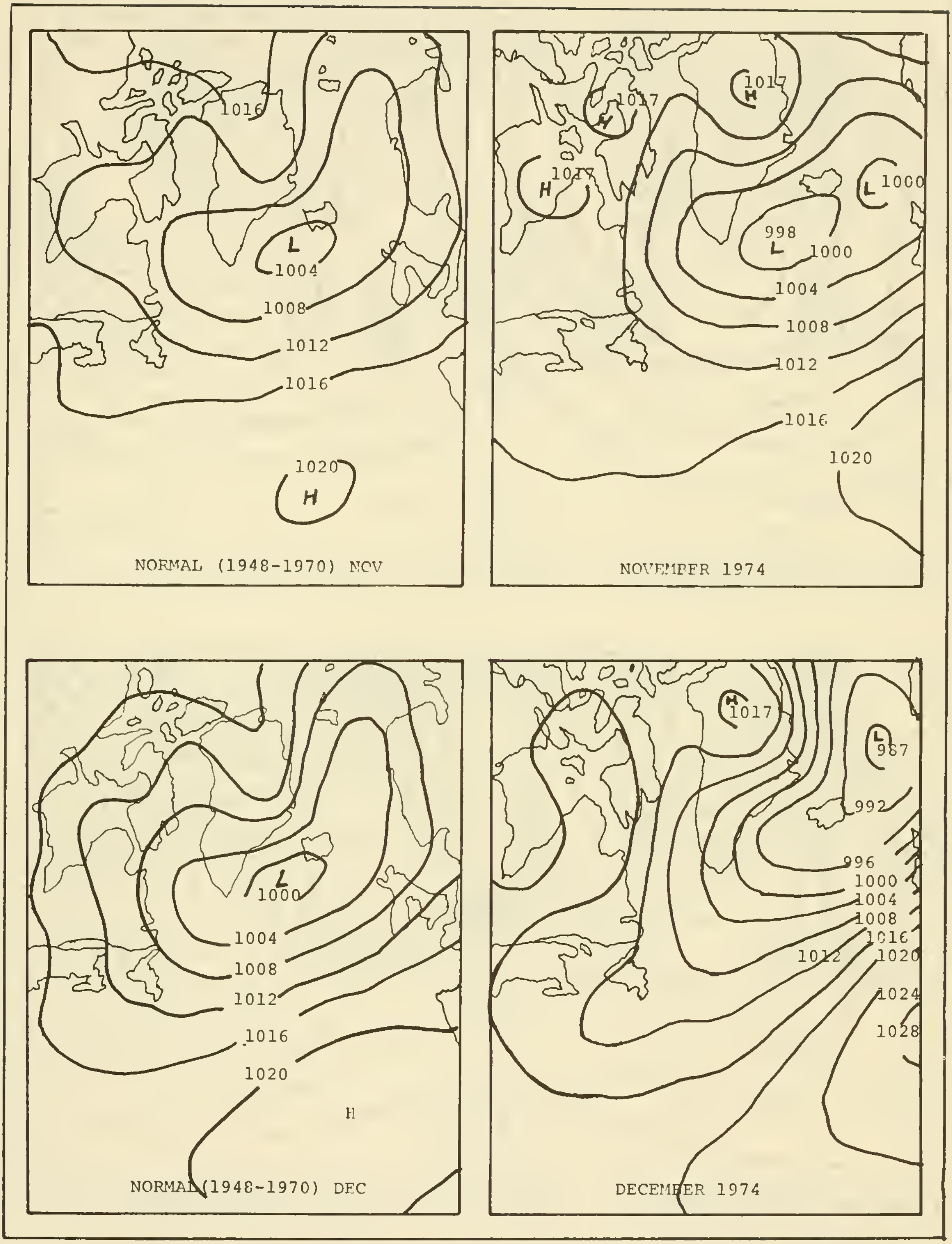

FIGURE 25A.—November and December Normal and 1974 Monthly Average Surface Pressure in mbs Relative to 1000 mbs

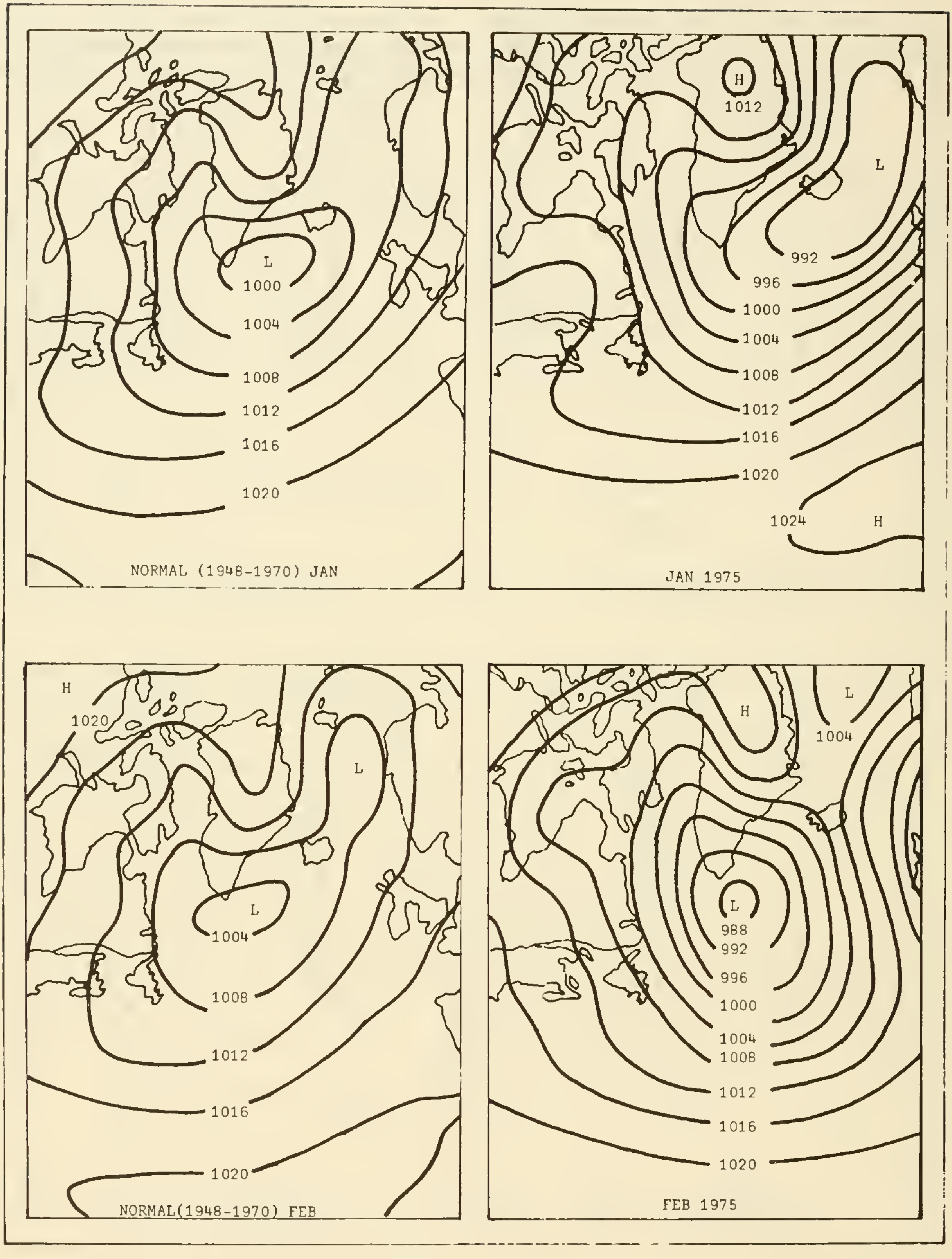

FIGURE 25B.—January and February Normal and 1975 Monthly Average Surfece Pressure in mbs Relative to 1000 mbs

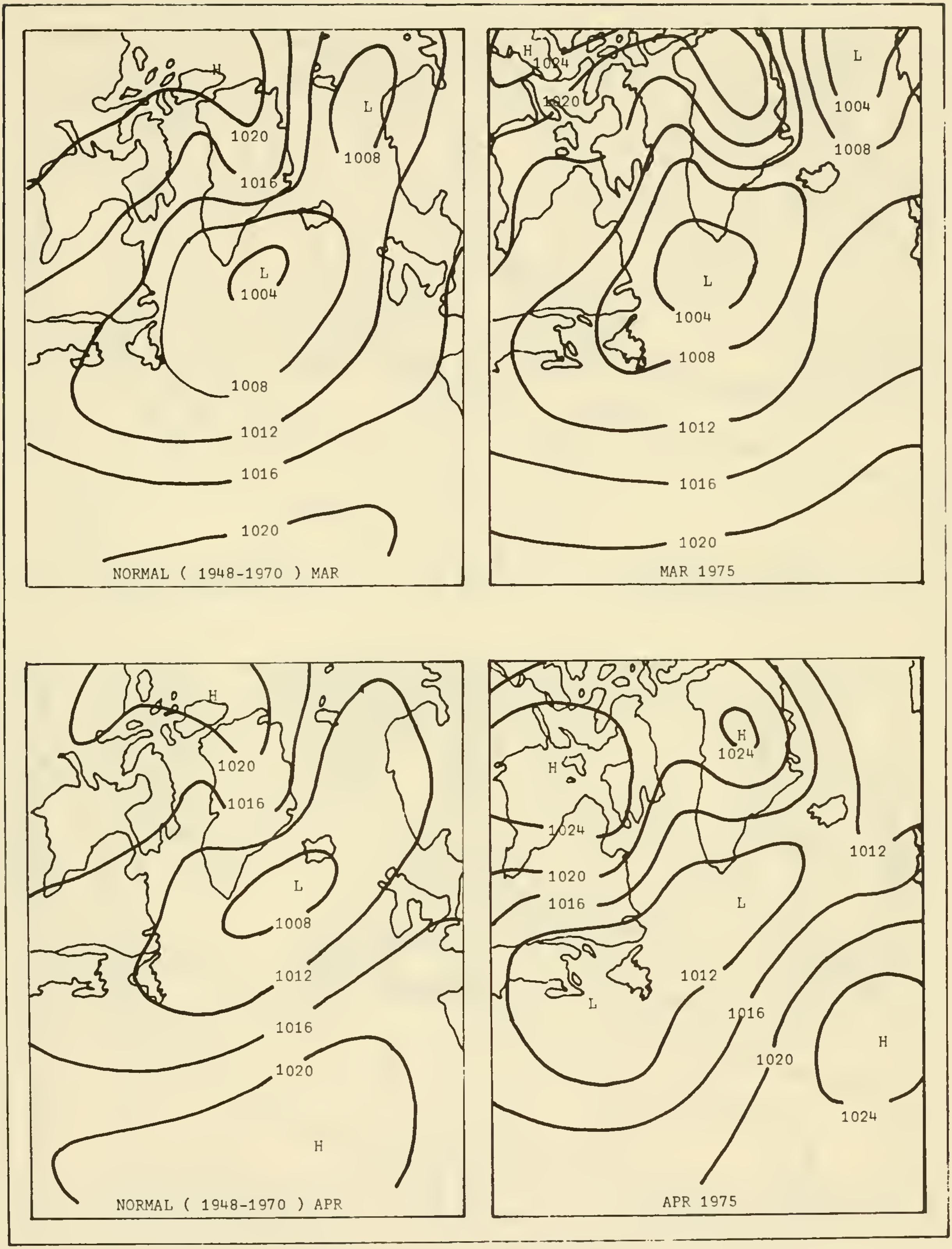

FIGURE 25C.—March and April Normal and 1975 Monthly Average Surface Pressure in mbs Relative to 1000 mbs

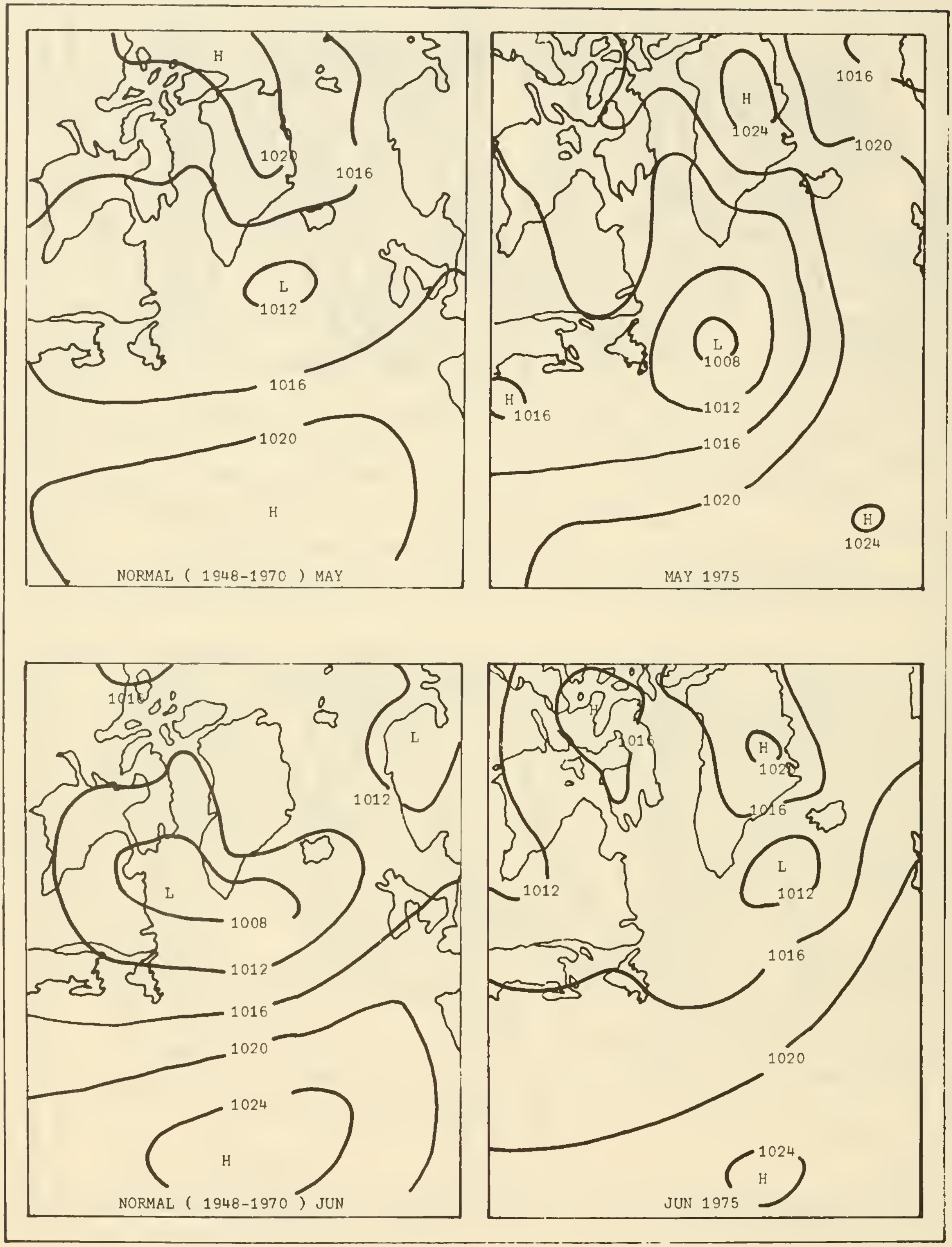

FIGURE 25D.—May and June Normal and 1975 Monthly Average Surface Pressure in mbs Relative to 1000 mbs

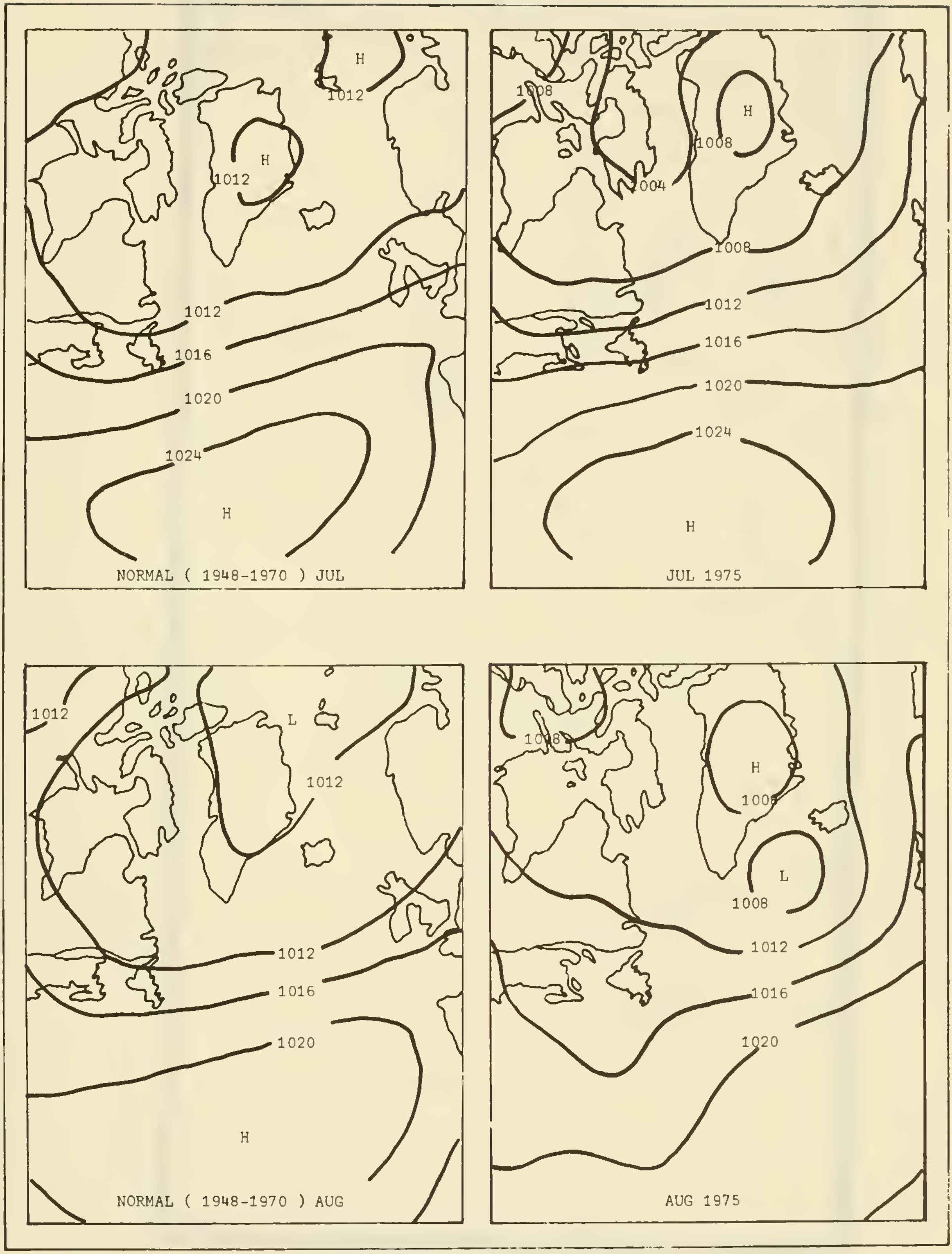

FIGURE 25E.—July and August Normal and 1975 Monthly Average Surface Pressure in mbs Relative to 1000 mbs

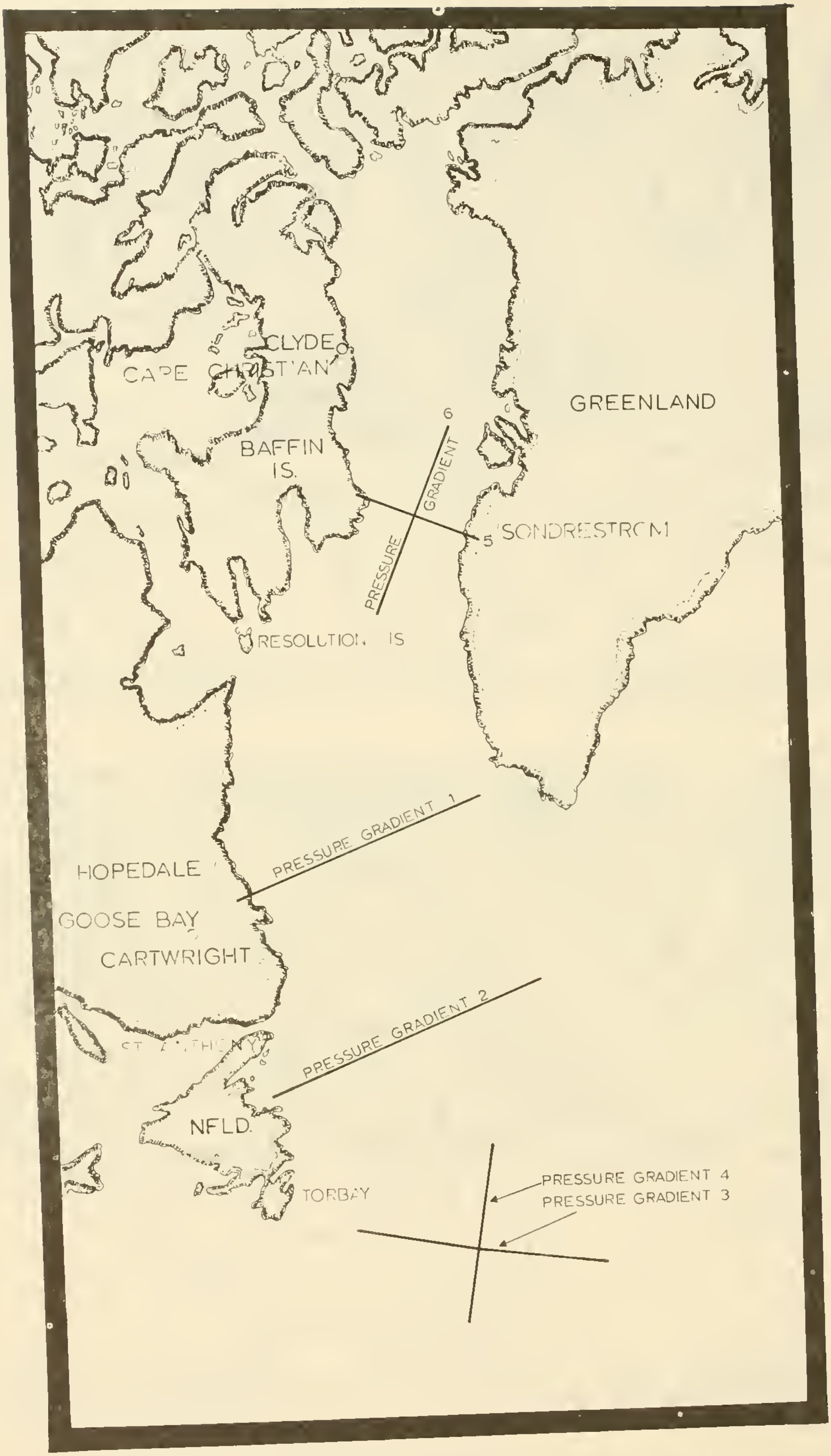

Figure 26.—Pressure Gradients Monitored by International Ice Patrol

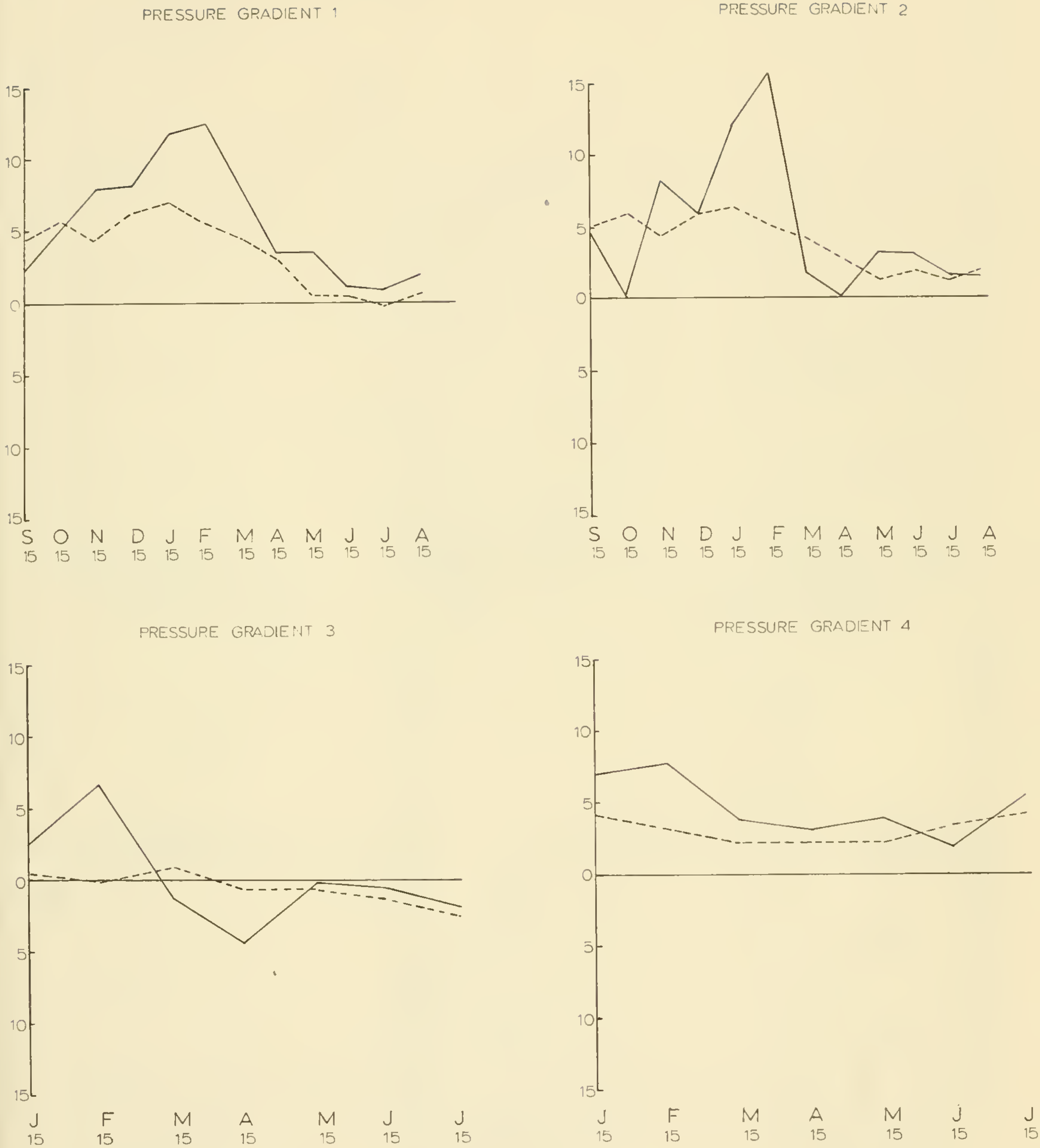

FIGURE 27.—PRESSURE GRADIENTS 1–4

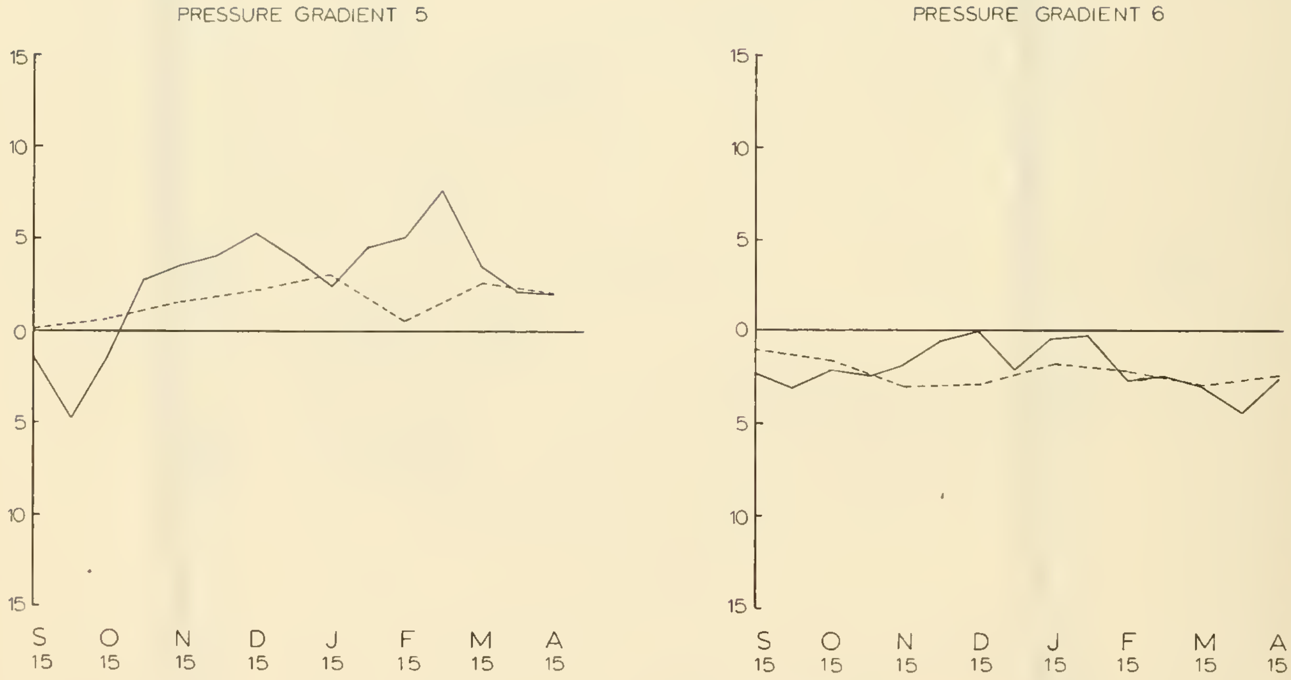

FIGURE 28.—PRESSURE GRADIENTS 5 and 6

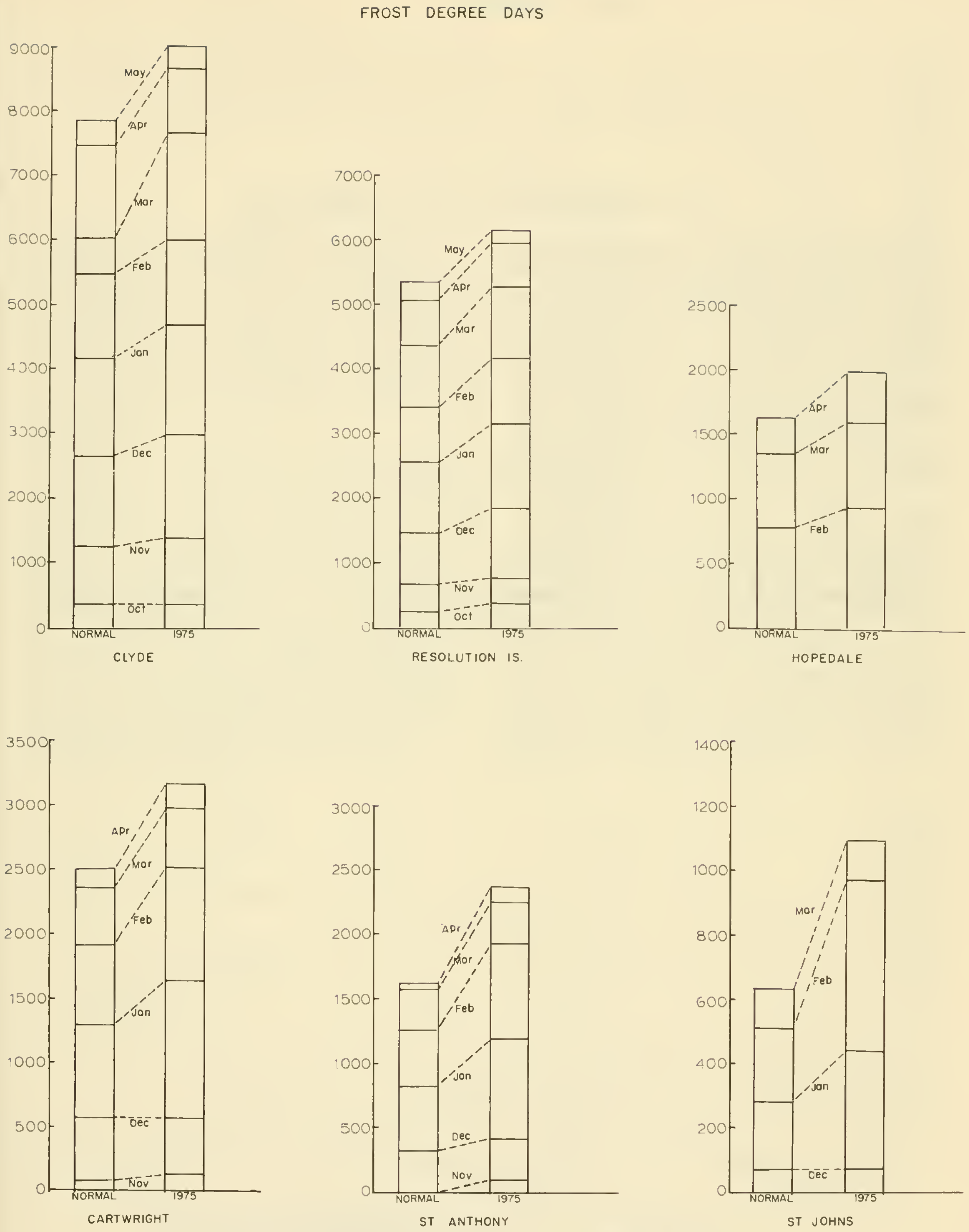

FIGURE 29.—Frost Degree Day Accumulations Calculated from Monthly Mean Fahrenheit Air Temperatures

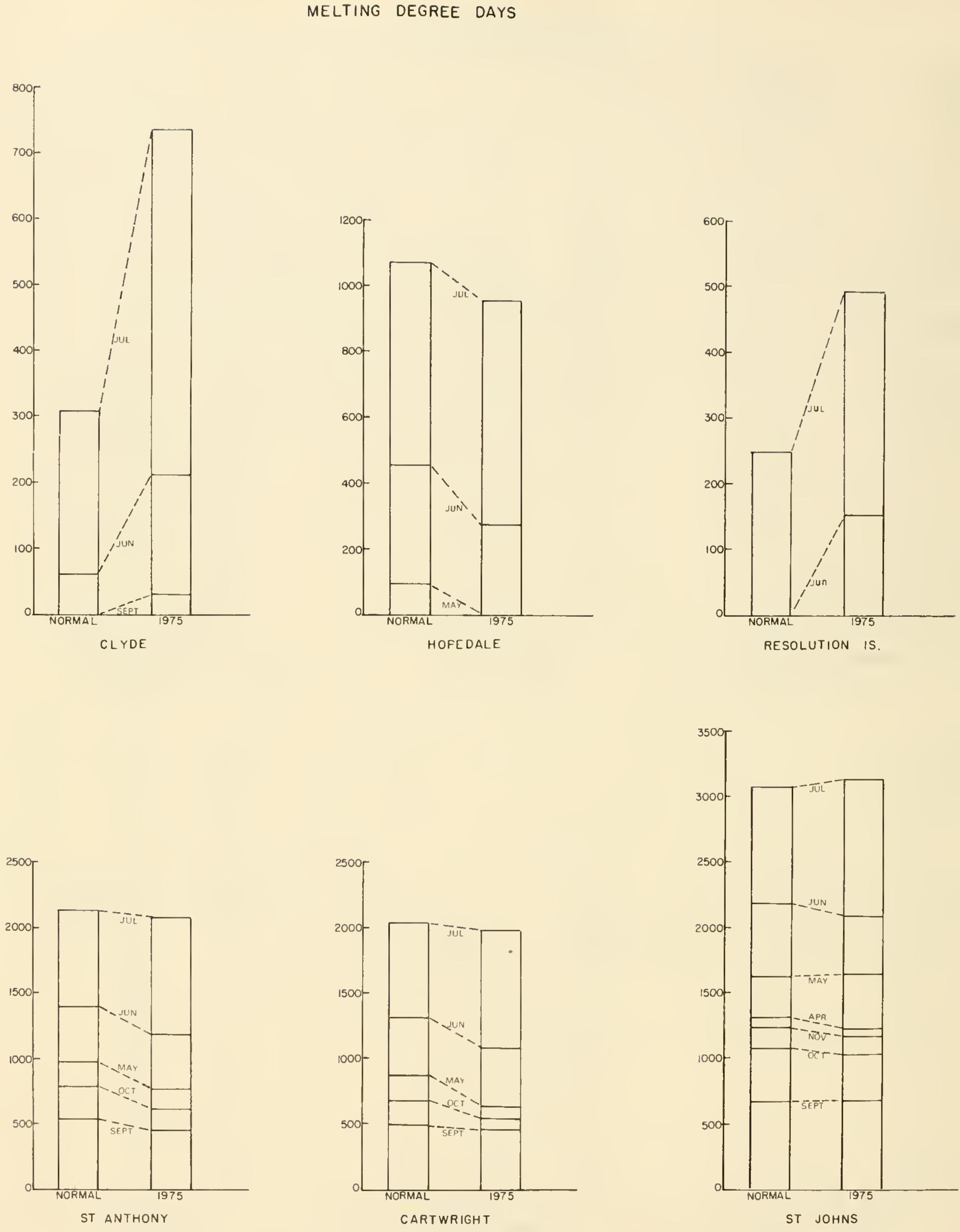

FIGURE 30.—Melt Degree Day Accumulations Calculated from Monthly Mean Fahrenheit Air Temperatures

RESEARCH AND DEVELOPMENT, 1975

Development of methods to tag icebergs for reidentification and drift analysis using various dye combinations continued with marginal success during the 1975 season. The natural instability of icebergs caused the dyes to be immersed and washed off. Calving would eventually result in several pieces of the original iceberg, dyed and/or clean, drifting off which would hinder identification.

An air deployed metal dart (penetrometer) was tested using the patrol aircraft and CGC SHERMAN as the surface observer. The penetrometer was thrown from the rear of the aircraft and would imbed itself in the face of the iceberg. A tag line with a wooden block was attached to the penetrometer. The surface vessel could then approach and replace the block with a transmitter for later location and identification using a direction finder. Further development of a reliable air deployable transponder would eliminate the need for a surface vessel and allow aircraft to tag icebergs on regular patrols.

Integrating current drogues were used for the first time by Ice Patrol. These drogues provided current data for iceberg drift experiments being conducted from CGC EVERGREEN. Half hourly wind data from shipboard anemometers and iceberg drifts observed visually or through ship's radar were recorded during these experiments. Empirical analysis of these data provided for increased understanding of the reaction of icebergs to the two primary forces responsible for their drift.

In April a NASA Lewis Research Center owned APS-94C Side Looking Airborne Radar (SLAR) was tested using the regular Ice Patrol aircraft to obtain simultaneous ground truth data for evaluation. Initial results indicated an outstanding target detection capability with very little target identification improvement over previous CG Research and Development Center findings. Follow on development of improved imagery interpretation is planned.

ICE AND SEA SURFACE TEMPERATURE REPORTS RECEIVED FROM SHIPS OF PARTICIPATING NATIONS DURING 1975

	ICE	*SST*
BELGIUM		
FEDERAL SCHELDE	1	
MINERAL SERAING	2	11
CANADA		
HUDSON	4	
HURON		14
JOHN A MacDONALD	1	
LABRADOR CCGS	2	
MARY B VI	1	
PROTECTEUR	2	
CHILE		
CARMEN		1
DENMARK		
CEDRELA		3
PACIFIC SKOU	1	
FEDERAL REPUBLIC OF GERMANY		
THEODOR STORM		2
WILHELM FLORIN		2
FINLAND		
COLONEL BILL	2	
FRANCE		
CETRA CARINA	1	
CETRA LYRA	1	
DELCHIM ALSACE		4
MONT LOUIS	1	
PELICAN	1	
SIBELIUS	2	1
GERMAN DEMOCRATIC REPUBLIC		
ANTARES	1	
ATLANTIC CINDERELLA	1	
MELLUMERSAND	2	5
MOSEL EXPRESS	2	
OTTO PORR		1
PEGASUS	1	

	ICE	*SST*
STADT BREMEN		12
STADT WOLFSBURG		11
TILLY RUSS		1
GREAT BRITAIN		
ARCTIC TROLL	1	
ATLANTIC CAUSEWAY	1	
CAST BEAVER	4	
C.P. DISCOVERER	2	
C.P. VOYAGEUR	2	
DART AMERICA	3	
DART ATLANTIC	1	
DUKES GARTH	1	
GLENPARK	2	
LAURENTIAN FOREST	3	
LONDON PRIDE		11
LONDON TRADITION	1	13
MANCHESTER CHALLENGE	5	5
MANCHESTER CONCORDE	3	1
MANCHESTER COURAGE		1
MANCHESTER CRUSADE		1
MANCHESTER QUEST	1	1
MANCHESTER ZEAL	1	
MOUNT EDEN		1
NORDIC PATRIOT	1	1
NORSE FALCON		6
ORIANA	1	
QUEEN ELIZABETH II	4	
TEXACO GHENT		4
TIDEFLOW	1	
TROLL PARK	5	
WELSH MINSTREL		2
GREECE		
ATHINAI		2
ARISTEES	1	
AVAX	1	
DRYMAKOS	1	
FEDERAL SEAWAY	1	
FODELE		3
JULIA LI		1
NORTHERN FROST	1	
PHILIPPA		1
STALO 2	1	1

	ICE	SST
ICELAND		
BRUARFOSS	1	
GODAFOSS	1	
SKAFTAFELL	1	
INDIA		
ANCOJYOTI	1	1
ATHELLAADKI		1
GAUTAMA BUDDA		1
JALAMOKAMBI	2	5
RATNAKIRTI		2
VISHVA KALYAN	1	
ITALY		
GIOVANNI AGNELLI	1	
SIRIO	1	1
TITO CAMPANELLA		2
JAPAN		
DAITOKU MARU	3	
TOYAMA MARU	1	
LIBERIA		
DELAWARE	1	
JOHANN SCHULTE	2	
MIDIGIRL		1
MORVEN	1	
OLYMPIC PROGRESS	2	5
RIO MACAREO	1	
UNIVERSE DEFENDER	1	1
MALAYSIA		
SCOL INDEPENDENT		4
NETHERLANDS		
AMSTELHOF	2	6
ATLANTIC CROWN	1	
ATLANTIC STAR	1	
CHIRIQUI		2
HOLENDRECHT	1	
MOORDRECHT	1	
NORWAY		
BERGE SIGLION	1	
BOW ELM	1	1
FOSSUM	1	
GEIRA	1	
HAVKATT	1	
IBEFJORD	1	
JOBOY	1	1
JOHN KNUDSEN		4

	ICE	SST
KIWI ARROW	3	
LIVANITA	1	3
ROSS ISLE	2	
TEAM GERWI	1	4
PANAMA		
HOLMA	1	
POLAND		
STASZIC	2	
STEFAN BATORY	1	
ZAWIERCKE	1	
SPAIN		
ERMUA	1	
LUJUA	1	
SWEDEN		
ATLANTIC SPAN	17	26
FORESTLAND	1	1
MONT ROYAL	2	2
SEGERO		3
UNITED STATES OF AMERICA		
AMERICAN ACE	1	
AMERICAN ARCHER	1	
AMERICAN LEGEND	1	
UNITED STATES COAST GUARD		
USCGC CHASE	2	
USCGC DEPENDABLE		2
USCGC DURABLE		1
USCGC EVERGREEN	30	790
USCGC NORTHWIND	1	
USCGC SHERMAN	2	49
UNITED STATES NAVY		
USNS MIRFAK	1	
USNS NEPTUNE	1	7
U.S.S.R.		
BRYANSKIY MASHINOSTROITEL	1	
KARCHAYUO CHERKESYA	1	
PIONEER ODESSY	1	
PIONEER VOLKOV	1	
RYBATSKAJA SLAVA	1	
YUGOSLAVIA		
RAVNI KOTARI		1

APPENDIX A

THE AVIATION HISTORY OF THE INTERNATIONAL ICE PATROL

By LTJG S. R. Osmer, USCG

"It seems to me a splendid practical use can be made of aeroplanes of the type which flew across the Atlantic, the NC type of plane. Two of these, one being for a relief vessel stationed at Trepassy Bay, Newfoundland, could with practically no trouble at all make a flying observation of the Banks and locate reported and unreported bergs during the short periods of clear weather, when a vessel of the type used on patrol could cover but a tenth of the distance and be further hampered by weather conditions at the surface."

CAPT. H. G. FISHER, USCG
Senior Officer
Summary of the Ice Patrol
Season of 1919

The 1975 Season marked the thirtieth anniversary of Ice Patrol aerial reconnaissance and surveillance. This was also the 63rd year of the International Ice Patrol, a service which has been conducted since 1913. The impetus to found such a service was provided by the tragic sinking of the RMS TITANIC on 15 April 1912, with the resultant loss of 1,513 lives. The service has been conducted every year with the exception of the war years, 1917 to 1918, and 1942 to 1945.

History and Transition

"The cautious and well-thought-out use of aircraft to assist during periods of fine weather in searching out the region in and near the critical triangle area just north of the B tracks would seem to be one of the most promising of the fields of development that are open to the ice patrol at the present time."

Season of 1929
Some of the Ice Patrol's
Problems, and How It Attacks Them

Historically, U.S. Coast Guard and International Ice Patrol aerial surveillance could be said to have its beginning in 1931 when the Coast Guard was invited by the Aeroarctic Society to assign an officer, experienced in ice patrol service, to be a member of the scientific staff of the dirigible GRAF ZEPPELIN, especially to observe ice and oceanographic conditions during her arctic flight. Lieutenant Commander Edward H. SMITH (later to be renowned as Admiral "Iceberg" SMITH) was assigned. The cruise lasted from 24 July to 31 July 1931. Among the conclusions of this flight was aerial surveillance of ice and ice conditions held great promise for the future.

The 1946 Ice Season commenced a new kind of International Ice Patrol. For the first time aircraft were utilized for iceberg reconnaissance. The first flights were made on 6 February with a PBY–5A CATALINA from the U.S. Coast Guard Air Detachment at Argentia, Newfoundland.

The shift to aerial surveillance led to relocation of the coordinating center from the patrol vessel to Argentia where the planes were based.

The 1949 Season marked the first time these aircraft were the only reconnaissance tools utilized. This was a light year, only an estimated 47 bergs south of 48°N, that did not require the use of surface patrol vessels.

The 1951 Season was the second year aircraft operated without surface vessel assistance. This season was so light, only 6 bergs estimated south of 48°N, that one of the two PB1G's was rotated between Argentia and its home base in Elizabeth City, North Carolina. This helped keep Ice Patrol operating expenses down, an important consideration when the bill is footed by consignatory countries. Today, nineteen countries pay for the Ice Patrol based upon their shipping tonnage traversing the area and benefiting from the Service.

May 1952 marked the only mishap occurring at Ice Patrol. A PB1G, making a landing at Goose Bay, Labrador, had one landing wheel collapse, damaging the underbody of the plane. Fortunately, there were no injuries. Rather than undertake repairs at a base so remote, parts and engine were salvaged and the airframe was abandoned.

For the first time in writing, in Bulletin No. 40 INTERNATIONAL ICE OBSERVATION AND ICE PATROL SERVICE IN THE NORTH ATLANTIC OCEAN—Season of 1954, aerial ice surveillance is deemed to be efficient. This can be viewed as a prelude to the final acceptance of aircraft as the primary mode of ice observation, reducing the surface vessel to a supplement.

In 1954, unsuccessful tests were conducted with a bolometer (forerunner of the airborne radiation thermometer) for the purpose of distinguishing between berg and non-berg radar targets under conditions of poor visibility. It had been hoped to identify objects by measuring changes in the radiant heat.

In 1960, the Ice Patrol yearly bulletin title was changed from "INTERNATIONAL ICE OBSERVATION AND ICE PATROL SERVICE IN THE NORTH ATLANTIC OCEAN: to "REPORT OF THE INTERNATIONAL ICE PATROL SERVICE IN THE NORTH ATLANTIC OCEAN". As was stated in the bulletin for the Season of 1960, the former title reflected a distinction made when the patrol was conducted by ships alone. The term "ICE OBSERVATION" was used during a search for ice information; "ICE PATROL" meant that ice information was available and being broadcast. The advent of aircraft reconnaissance and remote sensors, and the integrated activities of the plane, oceanographic vessel and patrol vessel now provided the continuity of information which permitted the unqualified use of the term "PATROL". In this bulletin, it is stated that aircraft are the tools of Ice Patrol, to be supplemented by surface vessels when conditions dictate.

The HERCULES was equipped with the Doppler Navigation System for the 1963 Season. The readout presentations provided the ice observer continuous track and cross track information, greatly increasing the accuracy of iceberg positions. Maneuvers off the prescribed track, once extremely difficult to plot, could now be readily charted.

Also during this season, an Airborne Radiation Thermometer (ART) was tested. Although the actual water temperatures recorded were considered not sufficiently reliable, the instrument was useful in detecting changes in surface water temperature, and therefore provided some help in locating the Labrador Current and its branches.

Bulletin No. 50, Season of 1964 states ". . . and the aircraft has become recognized as the primary tool for guarding the ice limits and for ice observation." This bulletin also states "Since 1949, the International Ice Patrol has recognized aircraft as the primary means for observing ice conditions and for guarding the limits of icebergs in the vicinity of the Grand Banks."

The 1966 Ice Patrol Season, besides being the lightest and shortest on record (zero bergs south of 48°N and lasting from 1 March to 28 April), marked the third and final year that Commander, International Ice Patrol was permanently stationed at Argentia. In June, the U.S. Coast Guard Air Station Argentia and the International Ice Patrol Argentia were disestablished. The International Ice Patrol was transferred to Governors Island, New York. The aircraft were transferred to the U.S. Coast Guard Air Station, Elizabeth City, North Carolina, and would in the future deploy to Argentia when ice conditions warranted.

A passive microwave radiometer (Model AN/AAR-33), with the frequency selected for optimum ice emissivity, had been installed on one of the Ice Patrol aircraft. A full evaluation could not be conducted this Ice Season due to continuing aerodynamic problems caused by the location of the microwave antenna dome.

The radar used in conjunction with the microwave radiometer enabled the ice observers to identify radar targets as steel ships or icebergs. Though excellent correlation was obtained with this device, it could not differentiate between wooden fishing vessels and icebergs. Another major shortcoming was the swath width—essentially only a narrow band beneath the aircraft could be identified. The aircraft could not fly over every target. The microwave radiometer was used through the 1969 Season.

In February 1970, the Ice Patrol was notified that the U.S. Naval Station at Argentia would

be phased down in the spring of 1970. The Ice Reconnaissance Detachment deployed to Argentia on 17 March, then redeployed to the Canadian Forces Base, Summerside, Prince Edward Island, on 30 April. Though this base was 500 miles to the west of the iceberg area, operations were conducted smoothly due to the excellent support provided by the Canadian Forces and by remaining overnight at St. John's, Newfoundland, when good weather had been forecast for several successive days.

A Side-Looking Airborne Radar (SLAR) unit (model AN/DPD–2) was evaluated commencing with the 1971 Season. It was hoped that SLAR would provide an all-weather detection device. Unfortunately, this was not the result, in this case mainly due to problems associated with the obsolescence of this particular unit. The evaluation concluded at the end of the 1973 Season.

The 1972 and 1973 Seasons were the first times since 1951 that a surface patrol had to be used to supplement aircraft due to the heavy ice conditions.

The 1973 Season saw the first use of the Inertial Navigation System (INS) in the reconnaissance aircraft. The system has been a most welcome addition, providing better accuracy for iceberg plotting.

St. John's, Newfoundland, became the base of operations for the 1974 Season. This move from Summerside resulted in a drastic reduction of enroute time to the area, with a corresponding increase in on-scene time.

An ART unit was evaluated in the latter part of the 1974 Season. The information provided showed great promise for real-time temperature data for iceberg deterioration and possibly for identifying the features of the Labrador and North Atlantic Currents.

In 1975 a newer SLAR model was evaluated. Though the final analysis of the data is not yet available, the conclusion probably will be that SLAR will enhance Ice Patrol but is not the final answer to its problems.

Objective and Conduct of Aerial Reconnaissance

The primary objective of International Ice Patrol is to guard the southeastern, southern, and southwestern limits of ice in the vicinity of the Grand Banks so that shipping might be advised of the extent of that dangerous area. In addition, the Ice Patrol has the purpose of maintaining a detailed, up-to-date picture of the ice situation in the Grand Banks region.

An ice patrol flight is normally between 1,000 to 1,500 miles long (approximately 6 to 8 hours of flight time) and the track is carefully laid out so that a maximum area can be searched for the miles flown. Two or three experienced ice observers accompany each flight. To insure the intended search area is actually covered and for accurate iceberg positioning, precise piloting and navigation is demanded of the aircrew. Search altitudes are usually between 1,000 and 1,500 feet and every effort is made to stay beneath the overcast and provide the observers with maximum visibility. The desired altitude provides an excellent range of sight, while still enabling many individual surface features to be discerned. While flights are usually made in good or fair weather, the prevalence of fog in the spring and summer months occasionally requires that a flight be made in marginal or poor visibility where the aircraft must seek out its targets by radar and then descend to gain visual identification of either ship or berg.

The problem of identifying targets during marginal or poor visibility has plagued the Ice Patrol for many years. The usual 25 mile flight track spacing is a compromise between maximum area coverage and maximum probability of detection. To obtain 100 percent visual coverage, an observer must have 12.5 miles of visibility on each side. When this visibility is not obtained, which unfortunately is fairly frequent, reliance is shifted to radar. From the altitudes flown, smaller bergs can usually be picked up by radar at about 10 miles. These radar targets can then be identified by diverting from the planned track, unless ceiling and visibility prohibit. With ceilings frequently below 500 feet, inability to identify a radar target as an iceberg or a vessel becomes a serious handicap. An iceberg cannot be ascertained from a moving ship on the aircraft radar scope due to the speed of the aircraft which masks the greatly lesser surface vessel's motion. Small bergs and growlers are not normally detected by radar if the range exceeds 10 miles or if sea conditions are moderate to rough. When sea conditions are severe, larger bergs may also be missed.

Even if the area of responsibility was smaller and more aircraft were available for ice observing to enable complete coverage, weather would rarely cooperate. One of the most important portions of the area is the Tail of the Banks, an area of complex oceanographic conditions, where the cold water of the Labrador Current meets the warm water of the Gulf Stream. This area is frequently plagued by dense fog which normally renders ice observation by aircraft ineffective for weeks at a time during the crucial periods of April, May, and June when icebergs can normally be expected at the Tail of the Banks.

During light seasons when ice is restricted to the northern Grand Banks, or when only a small number of bergs are menacing the Tail of the Banks, guarding the ice limits and ice observation can be effectively accomplished by aircraft alone. During years when many icebergs survive to the Tail of the Banks, aircraft alone cannot properly do the job. The Ice Patrol surface vessel may then be required. Extended periods of poor flying weather may compound the heavy iceberg threat, or by itself necessitate a surface patrol vessel.

Only twice since 1959 has a surface patrol been initiated. The 1972 Season was the heaviest on record, with an estimated 1587 icebergs drifting south of 48°N, and the longest, 29 February to 4 September, a total of 189 days. The 1973 Season found an estimated 847 icebergs drift south of 48°N and equalled the 1972 Season in length, 24 January to 31 July.

The mission of the surface patrol is to provide an on the scene guard over the southernmost or more hazardous ice when trans-atlantic shipping is, or is about to be, menaced.

A surface vessel can search but a small portion of the area necessary to determine the ice limits. However, an aircraft on a day with good visibility will determine a large portion of the limits and observe the ice within these limits. Within a day or two after determination of the ice limits by aerial observation, ice conditions, and consequently ice limits, may have drastically changed. From the initial reported positions, Ice Patrol Headquarters will be drifting the icebergs using a computer drift model which considers wind and sea current conditions. Another effective ice observation flight may not be possible for days, during which time, the Ice Patrol vessel can search out the most dangerous areas and locate, observe, and guard the most dangerous icebergs, warning ships accordingly.

Thus, when large numbers of icebergs threaten and the aircraft and Ice Patrol vessel are both required, they complement each other in carrying out the mission of the International Ice Patrol. Since virtually all ice observation functions are accomplished now by aircraft, it is possible to confine surface patrols exclusively to known or suspected ice-inhabitated regions.

This combined air-surface procedure obviates the necessity for long and costly surface vessel searches that were characteristic of the years prior to 1946.

The Future

For the foreseeable future, aerial ice surveillance will remain the primary tool of Commander, International Ice Patrol, supplemented by a surface patrol when conditions warrant. The conduct of the flights will most likely remain as at present.

The advantages of aircraft over the surface vessel are impressive, namely increased area coverage in a greatly reduced amount of time. One disadvantage of aircraft replacing the surface vessel has been, as stated in the bulletin for the Season of 1964, a loss of continuous monitoring of specific icebergs that the cutters used to maintain. With aerial reconnaissance, an iceberg may be resighted only after a lapse of many days. Even then its identity may not be known with certainty. If iceberg dynamics are to be totally understood, surveillance of icebergs must be continuous. Weather often precludes this with aerial reconnaissance. Thus, there exists a pressing need for an all-weather remote sensor for Ice Patrol, capable of locating and enabling positive identification of targets.

By following this partial history of the Ice Patrol, it is apparent that the Ice Patrol is deeply engaged in research toward the goal of providing the best product available, at the lowest cost. To this end, Commander, International Ice Patrol is researching for the immediate future utilization of an operational all-weather system. Perhaps a package similar to the U.S. Coast Guard Airborne Oil Surveillance System (AOSS) or a present SLAR model will provide the all-weather detection capabilities desired.

When capable remote sensing systems are acquired, Ice Patrol will enter the third phase of its development: Phase I—Surface Patrol Vessel Scouting; Phase II—Aircraft Surveillance; and Phase III—Remote Sensing. This might well be in conjunction with a longer range model aircraft, which could facilitate operating from a base more remote from the Grand Banks region.

The final phase, as envisioned by the author, is Phase IV—Satellite. As the state of this art rapidly improves and becomes available, it should be possible in the near future to utilize either a geo-stationary satellite or one providing rapid repeat all-weather surface coverage of the area. This satellite would have the resolution to monitor individual icebergs and ice conditions and movement. On board sensors would measure the environmental conditions. The satellite would then broadcast the data to a receiving station for analysis prior to broadcast, or the satellite would develop the data itself and broadcast to shore transmission sites and direct to mariners. This latter method would be the most efficient and lowest cost to Ice Patrol.

To conclude, the International Ice Patrol renders an invaluable service to all mariners. Since the Patrol's inception, not a single ship has been sunk due to striking an iceberg outside the limits of all known ice as broadcast by the International Ice Patrol. Records show that ships have collided with bergs and sank inside these limits, indicating that the warnings were not heeded and ships steamed through the danger area. Outside the Patrol's area of responsibility several modern ships have hit bergs and sank. Most notable are the M/V HANS HEDTOFT on 30 January 1959, and the M/V BERGEMEISTER on 25 November 1965, both off Kap Farvel, Greenland. Thus, the unblemished record of Ice Patrol should not be allowed to lull anyone into a false sense of security, nor should this check Ice Patrol's improvement through scientific research.

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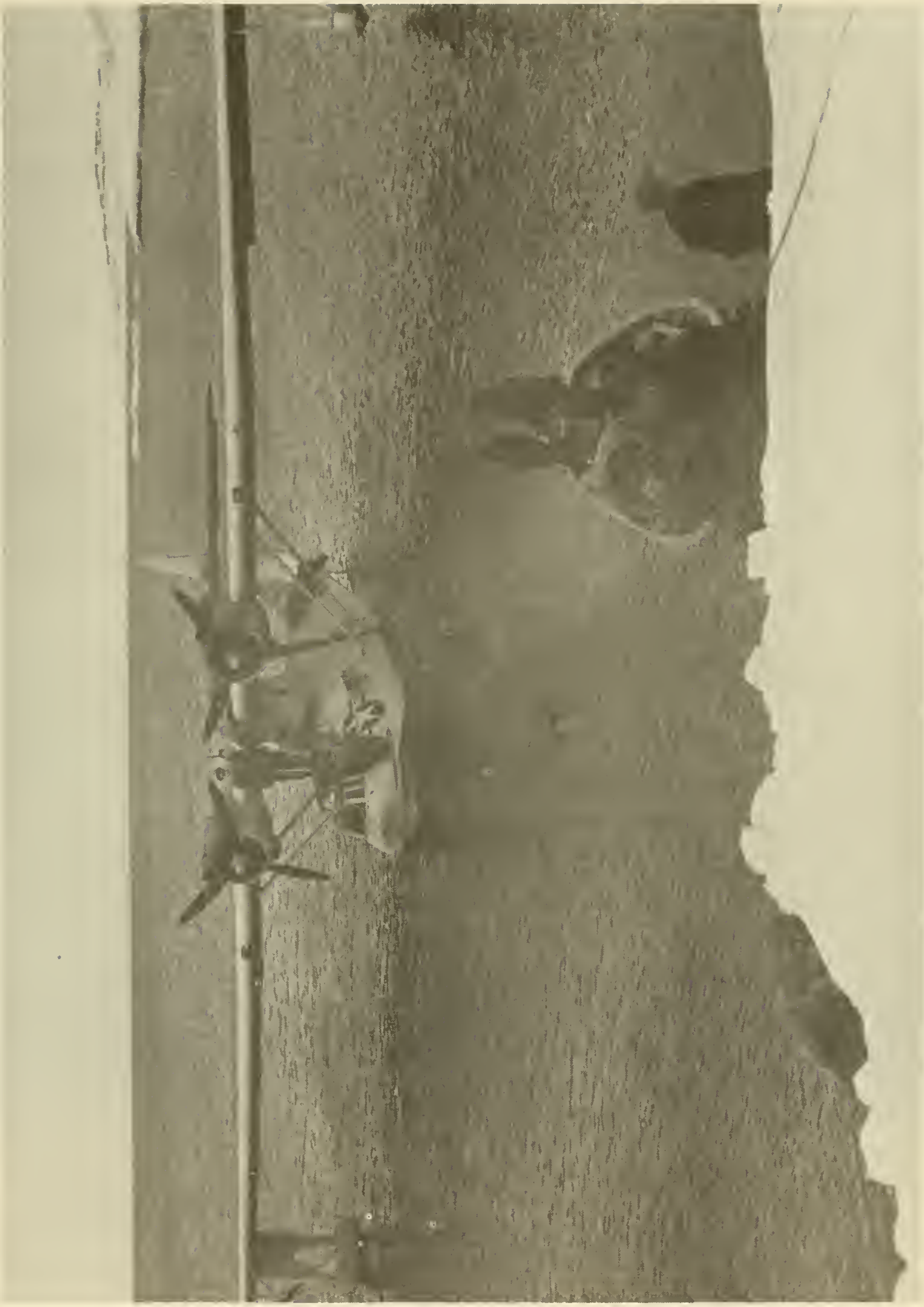

FIGURE A–1.—A Coast Guard PBY–5A Catalina. This aircraft was used on the first aerial reconnaissance flights conducted in support of the International Ice Patrol in 1946.

FIGURE A-2.—A Coast Guard HC-130-B aircraft. This type of aircraft has been used by Ice Patrol since the late 1950's.

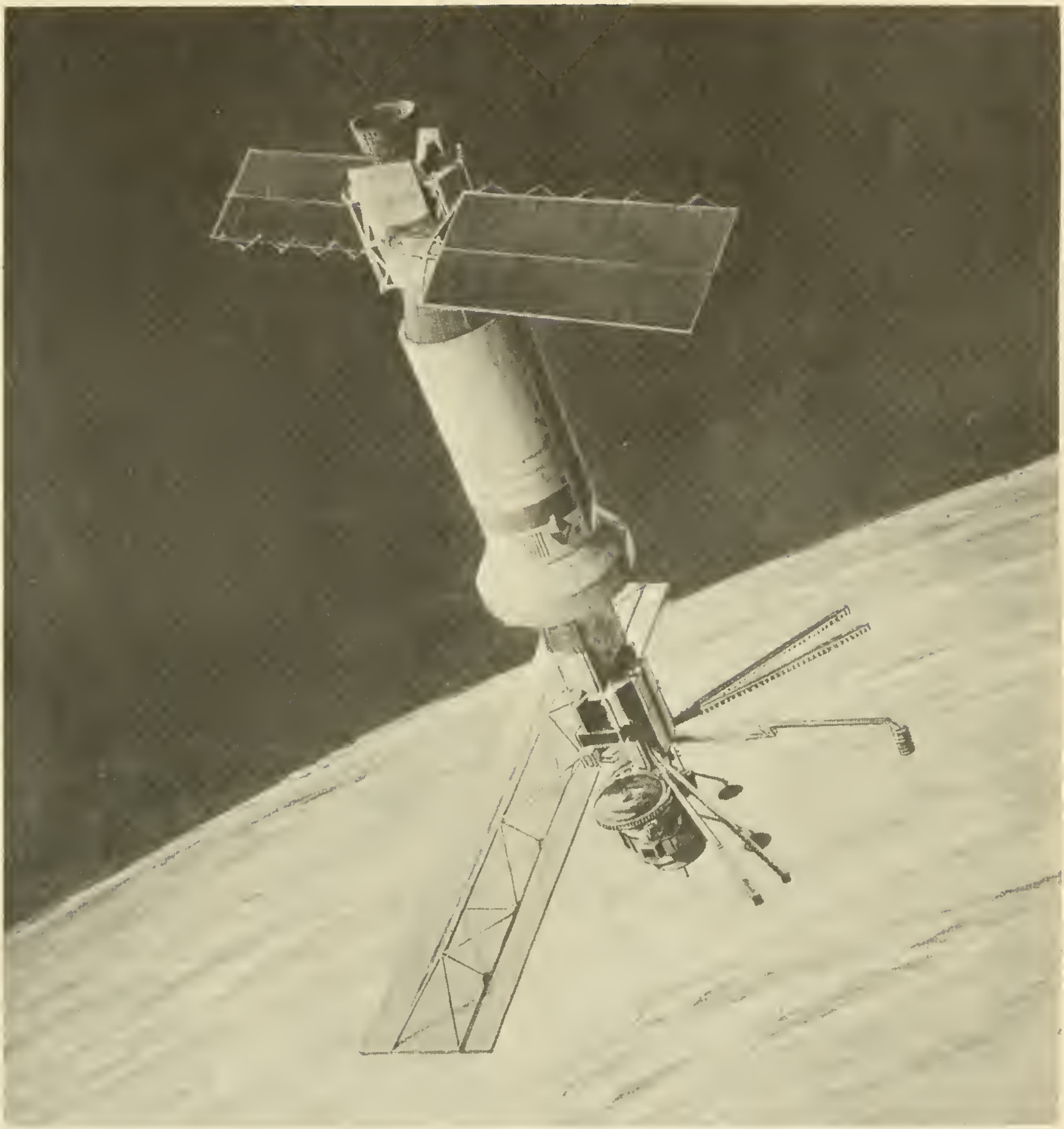

FIGURE A–3.—SEASAT–A due for launch in May 1978. This is planned as the first in a series of satellites designed to monitor the oceans. These satellites could prove invaluable to Ice Patrol, possibly eliminating the need for routine aircraft reconnaissance by the late 1980's.

APPENDIX B

REMOTE SENSING AS IT APPLIES TO THE INTERNATIONAL ICE PATROL

CDR A. D. Super, USCG

LTJG S. R. Osmer, USCG

Icebergs calve from the major glaciers of Greenland. As many as 10,000 are produced each year. Although exposed to open sea and warmer water in the summer and fall, these bergs become trapped in and protected by sea ice during the remainder of the year. Those that survive, travel with the pack ice from Baffin Bay to the western Labrador Sea and start to arrive off the Newfoundland coast in January and February. The bergs exit the sea ice to the south and east, continuing their drift until they eventually melt in the warmer North Atlantic water. As the pack ice recedes in late spring, bergs continue to survive south of latitude 48°N until mid to late summer when warmer water and open seas normally deteriorate them before they can reach the main shipping routes. The annual average number of bergs crossing latitude 48°N to menace shipping since WWII is 318, although season severities have varied from 1587 bergs in 1972 and 1387 in 1974 to 0 in 1966 and 1 in 1958.

The Grand Banks and its approaches are uniquely hazardous to shipping for a number of reasons. Foremost of these are: the high density of shipping, extremely rich fishing grounds, great frequency of bad weather and poor visibility, and the intrusion of pack ice and icebergs. The shortest routes between the major ports of North America and Europe pass through this area. The interchange of the cold, southward flowing Labrador Current with the warm North Atlantic extension of the Gulf Stream fosters both a nutrient rich fishing ground and a great profusion of fog. Additionally, North American storm tracks usually cross this area.

There are two possible approaches to make the area safer for shipping. They are: (1) elimination of the hazards and (2) location of the hazards with wide dissemination of location information so that they may be avoided. In attempts to destroy bergs, Ice Patrol has carried out a number of experiments including gunfire, demolition mines, high explosive bombs, thermite bombs, and carbon black without significant success. Destruction of the bergs is not feasible. Thus, Ice Patrol collects iceberg location information and disseminates warning information to shipping as widely as possible.

One might presume that, with modern surface radar, ships could detect and avoid icebergs. Aside from human errors of nondetection this is found to be untrue. In 1959 an extensive study of ice detection by radar was completed. This work determined the behavior of floating ice to electromagnetic radiation and assessed the efficiency of radar in providing reliable information for safe navigation through potential ice areas. A summary of the results are:

1. Ice typical of that in icebergs on the Grand Banks has a reflection coefficient of approximately 0.33 and reflects radar waves 60 times less than a steel ship of equivalent cross sectional area.

2. The maximum range of radar contact is proportional to the fourth root of the physical cross-sectional area of icebergs. A statistical relation derived from 152 observations shows that growlers (above water area of less than 1 x 6 meters) normally cannot be detected at ranges over 4 miles.

3. The Grand Banks and continguous areas of the North Atlantic exhibit conditions of subnormal radar propagation during the spring months when fog and ice hazards are most prevalent.

4. Waves over 1 meter in height might obscure a dangerous growler even with the expert use of anticlutter devices. If an ice target is not picked up beyond the sea return, it will not be detected at all.

5. Ice is not frequency sensitive. The response to S and X bands is the same. Furthermore, there is practically no difference in the response of sea water to S and X bands.

These results remain valid today. This past year, one merchant vessel collided with ice within the Ice Patrol broadcast limits of all known ice and incurred considerable damage and a small coastal freighter was lost with 6 lives following a collision with a berg in Hudson Strait. Often Coast Guard surface patrol vessels lose ice targets on radar while tracking them in close proximity.

Ice Patrol's early airborne remote sensing ventures consisted of aerial photography and conventional airborne radar. The reconnaissance aircraft usually flies standard tracks at an altitude of 1,500 feet in good weather over areas of probable icebergs. Radar data establish the actual position of berg sightings. With the prevailing low ceiling and minimum visibility, the reconnaissance aircraft attempts to descend just below the ceiling to a minimum of 400 to 500 feet. Diversions from assigned tracks are then made, when possible, to attempt visual identification of radar targets. The dangers inherent in this type of operation are obvious. Often the predominance of fog reduces reconnaissance effectiveness to zero. The problem encompasses not just target acquisition but that of classifying all detected targets as icebergs or nonbergs. The first attempt in this area was unsuccessful tests with a bolometer (forerunner of the airborne radiation thermometer) in 1954. Additional ART tests were conducted in 1964 when, although iceberg identification was not enhanced, basic current structure was deducted from the sea surface temperature on several occasions. An AN/ARR–33 passive microwave radiometer was flown from 1967 through 1969 with moderate success. Some targets were positively identified as bergs, although the fixed nadir window required overhead identification of all of the myriad of targets. A precision radiation thermometer (Barns PRT–5) maps sea surface temperature for use in iceberg melt determinations and approximation of major current features. In essence, these are the only operational tools today that supplement visual observations. Additionally, application of NOAA 4 high resolution infrared and visual imagery to obtain these data are being pursued.

As early as 1957, Ice Patrol conducted experiments with Side Looking Airborne Radar, because it was apparent that the high resolution would provide near all-weather detection and identification. This work, using an AN/APQ–55 (XA–1) K-band real aperture system, was limited to scope due to poor electronic reliability but provided great hope for future systems. In 1969 Ice Patrol commenced experiments with a modified AN/DPD–2 Ku-band, real aperture SLAR system to evaluate its capabilities. From data obtained on regular patrol flights in 1970 and 1971, the Coast Guard Research and Development Center formulated a system of target discrimination between icebergs and other objects through interpretation and classification using analysis of basic clues. Seven clues consisting of size, shape, shadow, tone, texture pattern, edge and wake were considered. A photographic interpreter would analyze each target for convergence of evidence in a "logical search" phase. This system proved quite satisfactory and reasonably reliable for post mission research analysis but was operationally constrained by the requirements to develop film (a vacuum in flight developer was not available), the extensive amount of imagery to be viewed, and the near-laboratory conditions required for handling enlarged imagery which were not available in the field. The AN/DPD–2 SLAR was again flown during the 1972 and 1973 seasons, but its use was terminated due to continuing maintenance problems with this aged system and the imagery handling problem.

As a follow on to previous work in support of the Great Lakes Navigation Season Extension Demonstration Program during the winter of 1975, NASA Lewis Research Center installed an AN/APS–94C modified SLAR system in a Coast Guard HC–130B aircraft. At the conclusion of Great Lakes season, this system, with additional modifications and the Moving Target Indicator mode installed, was flown experimentally in support of the International Ice Patrol. An Edo-Western dry film processor was installed in the aircraft and data transmission modes were not utilized. Twelve missions were flown with the

SLAR aircraft at desired altitude while the regular reconnaissance aircraft provided surface verification flying routine search tracks and investigating all SLAR targets. Missions were flown over the open water iceberg areas of the Grand Banks and into the pack ice area upstream along the Labrador coast. Various adjustments to the system were made with a wealth of good data. Results were basically as expected. The systems provided greatly increased coverage and effectiveness, obtained all targets including whales and debris, easily detected icebergs in sea ice and penetrated all weather except heavy rain. Small bergs were consistently detected to 48 kilometers with a signal to noise ratio of at least 2. The basic problem continued to be target identification. Other problems were: slow target geographical location by manual plotting, sea return interference, and antenna fade. The Moving Target Indicator mode provided unsatisfactory results mostly due to equipment performance and slow target movements in azimuth. The Ice Patrol and NASA Lewis plan to continue experimental SLAR flights during the 1976 ice season attempting to solve the target discrimination and data handling problems. Additional modifications will include: a moving window display with automatic target designation, several approaches to automatic target recognition and identification, better amplitude-time discrimination, and depolarization of echoes.

The future looks promising. The Coast Guard prototype Airborne Oil Surveillance System (AOSS) has been flight evaluated and will soon be installed in a service C–130 aircraft. This system includes an AN/APS–94D SLAR, a 37–GHz passive microwave imager, a multispectral line scanner and a low light television system with position reference and real-time processor/display console. AOSS was originally developed for marine pollution detection and cleanup support, but will be used in other Coast Guard mission areas, particularly the International Ice Patrol. A multisensor system with separate detection and interrogation functions is another approach to be evaluated. Other advances with good potential of target identification are the use of synthetic aperture systems and a dual mode operation with low resolution, broad swath search and narrow width, high resolution scrutiny. But these are presently beyond Ice Patrol's limited funding scheme. Ice Patrol is also well represented on the SEASAT user working group and, in the long-term, envisions such a satellite to continuously monitor the area of responsibility, not only detecting sea ice and icebergs, but also providing needed surface environmental data.

But that is in the future. Today Ice Patrol is still plagued by its old nemesis, fog, while continuing to guard the Grand Banks against another TITANIC disaster.

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APPENDIX C

"SEARCH" COMPUTER PROGRAM DESCRIPTION

By R. Q. Robe

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"SEARCH" is a computerized data storage and retrieval system adapted to International Ice Patrol (IIP) dynamic height data requirements. All historical dynamic height data are indexed by 20 minute latitude and longitude intervals, month, and year. "SEARCH" permits monthly and yearly comparisons to be made between dynamic heights on file. The method used is to calculate the sum of the squares of the differences in dynamic height for corresponding locations between the month and year of interest and all other month and year data sets on file. Squaring the difference eliminates negative values prior to summing. The sum of the squares of the difference in dynamic heights between the reference month and a historical month is calculated only for the area of common geographical coverage. When all sums of squares of differences in dynamic height have been calculated, they are ranked from least sum upward. The sum of the squares value should be treated as an ordering index only and does not have any physical significance. "SEARCH" also supplies the number of dynamic height data points in each of the sets (month and year) used in the comparison and the number from each set that coincide with those of the reference set.

The "SEARCH" program output is designed as an aid to IIP oceanographers in making better use of the dynamic height data collected each season by the IIP oceanographic vessel. It is based on the assumption that history repeats itself to the extent that over a large number of years the current systems in the IIP area of interest will show characteristics which are similar to other seasons. The months and years picked for use from the ordered list by the oceanographer should have a low sum of squares and a high percentage of data locations in common with the reference month.

An example will be instructive. Input 96 dynamic height data points from May 1975 as the reference month. Comparisons are made with data file and the following output is produced. The oceanographer would then scan the output and take a closer look at those months which have a low sum of squares (the output ranks only the top 25 possibilities) and also a high number of data point locations in common with the reference month. Probably the best months to look at would be April 1959, May 1959, June 1959, May 1952, April 1939, and May 1958. The dynamic height charts for these months can be examined for the best qualitative fit with the reference month. From this point, those months which compare well can be used to qualitatively extend the boundaries of the survey area and aid in matching the contours of dynamic heights of the reference data to those on the IIP normal charts (which are included in the data file along with the historical data). In this example, May 1975 compared well with April, May, and June 1959. Thus it is likely that the current system in 1975 would be very similar to that in 1959. Given the same availability of icebergs in both years, similar drift patterns can be expected.

SEASONS THAT BEST COMPARE WITH MAY 1975

NR	*Closest Match*		*NR OBS*	*Least Square*	*Matched Points*	*Percent*
1	April	1959	237	721	96/96	100.0
2	May	1959	238	2685	88/96	91.7
3	April	1954	248	3348	50/96	52.1
4	April	1965	76	4784	35/96	36.5
5	May	1969	62	5028	3/96	3.1
6	April	1948	39	5701	19/96	19.8
7	May	1968	112	6196	40/96	41.7
8	April	1970	206	6551	29/96	30.2
9	June	1959	400	6614	92/96	95.8
10	June	1934	175	6717	20/96	20.8
11	June	1964	206	7401	68/96	70.8
12	June	1950	167	8481	66/96	68.8
13	April	1968	130	8575	59/96	61.5
14	May	1939	85	8667	70/96	72.9
15	May	1948	61	10228	51/96	53.1
16	April	1972	118	10614	25/96	26.0
17	April	1966	25	10727	4/96	4.2
18	May	1952	270	11165	82/96	85.4
19	June	1954	462	11361	80/96	83.3
20	June	1939	175	11524	81/96	84.4
21	June	1972	52	11530	13/96	13.5
22	April	1967	51	11587	9/96	9.4
23	April	1939	196	11779	92/96	95.8
24	June	1968	127	12079	61/96	63.5
25	May	1958	409	12577	92/96	95.8

In summary, this is a qualitative, not a quantitative tool. It is not designed to give definitive answers to the current velocity prediction problem, but rather to aid the IIP oceanographer to a better understanding as to how the ice season is developing and how to combine the present data, which cover a limited area, with the IIP normal dynamic height charts, which cover a large area.

APPENDIX D

PHYSICAL PROPERTIES OF ICEBERGS TOTAL MASS DETERMINATION

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and

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Analysis of stereo pairs of twenty-two icebergs, in the region of Davis Straits, reveals that a reasonable estimate of total iceberg mass, in metric tons, can be arrived at by multiplying the gross dimensions of the iceberg (height x width x length) together and the multiplying this product by a factor of 3.01. This factor accounts for the density difference between seawater and fresh water ice; it also accounts for the average shape and mass distribution of icebergs.

Introduction

Before a model for the deterioration of icebergs can be constructed and verified, it is necessary that actual observations be made of icebergs melting and calving. A prerequisite for deterioration observations is a simple technique for the determination of iceberg mass. KOLLMEYER (1966) determined the mass of icebergs by constructing a contour map of the berg using horizontal photographs taken at intervals of every 30° of arc around the berg. This technique was very laborious, not very accurate, and could not be used to cover many bergs. We felt that a more practical approach was to use aerial photography and construct a topographic type map of the bergs from stereo pairs. Since we lacked any vertical control points, such as exist on land, horizontal and oblique photographs were taken to provide a measure of vertical scale.

In order to obtain the necessary photography the CGC EDISTO was used for a platform for two HH52 helicopters. The EDISTO was assigned to this project from approximately 16 July 1974 until 4 August 1974. The first icebergs photographed were just north of Goosebay, Labrador. From there the EDISTO proceeded north, until just north of the Arctic Circle, working icebergs as we went. From the Davis Straits area just north of the Arctic Circle we proceed south and then east in order to pick up icebergs off the west coast of Greenland.

Data Collection

Thirty-two icebergs were photographed. Of these, twenty-one were of high enough quality to determine the above water volume. Hydrographic stations taken near each iceberg measured the average density of the seawater in the area.

Aerial photography was acquired from USCG HH52 helicopters, using 500 EL Hasselblad 70 mm format cameras with 100 mm f3.5 lenses. These cameras were installed in a lightweight aerodynamic camera mount designed at the CG R&D Center. The mount is a lightweight (85 pounds with four cameras) multi-purpose unit which requires no airframe modification for installation. Design limits are air speeds 140 knots or less and unpressurized flight altitudes. The practical limiting altitude is 6,000 feet. The mount is designed to fit all Coast Guard aircraft capable of meeting these limits.

Parallax measurements used in determining heights of points on the iceberg were made on stereographic photographs with the model 121 GE stereo comparagraph. Sea level cross-sectional area was measured with the B&L photo data quantitizer.

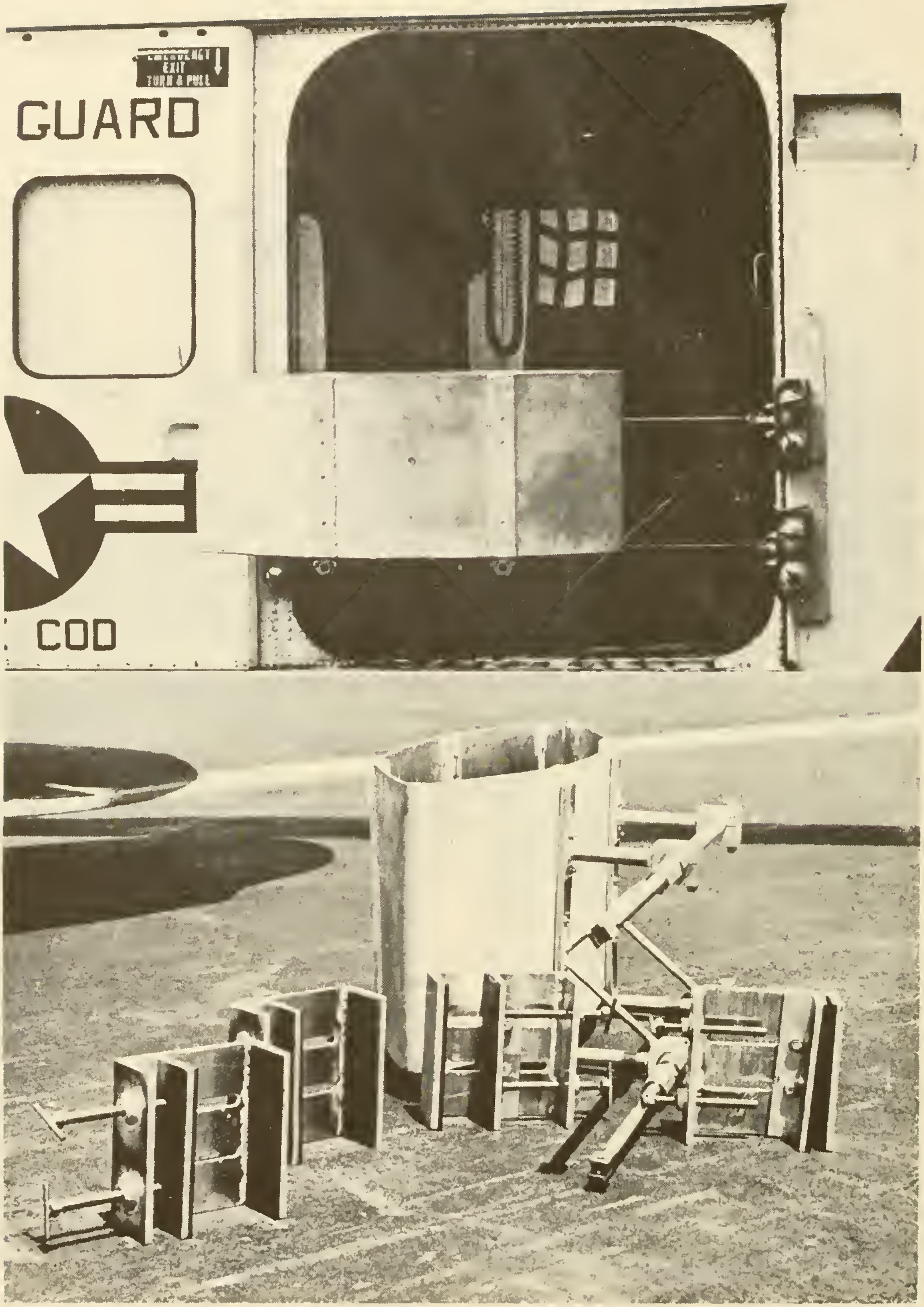

FIGURE D-1.—Multi-purpose, portable camera mount

To accurately determine the total mass of an iceberg, the above water volume and mass must first be determined. This involved three types of photographs; horizontal, oblique and vertical. In all cases the 500 EL/M 70mm cameras were used. Black and white negative film was used, with all analysis done from positive prints.

Horizontal and oblique photography was obtained by using a leveled tripod from inside the helicopter. Slow, level passes at selected altitudes and offset distances were made at four locations around the iceberg. These were usually 90 degrees apart. Both horizontal and oblique photographs were obtained at each station. Vertical photography was obtained using the previously described camera mount. Adequate overlap was obtained by taking repetitive frames at predetermined time intervals. Utilization of each type of photography is explained in the pilot study and analysis sections which follow.

Pilot Study

After several attempts to contour the iceberg in a manner similar to a topographic map, we came to the conclusion that such a straightforward method was impossible due to the extreme surface gradients found on a typical iceberg. A new approach was then tried which proved successful. A grid of randomly selected points was used to locate the position of the parallax measurements. Since no point on the berg was more likely to be sampled than any other, it was possible by sampling a sufficient number of randomly selected points to determine the average height of the iceberg to any desired accuracy. An accuracy of better than ± 2 meters was chosen and a pilot study was conducted to determine the sampling density required. It was determined that a sampling density of .02 points per square meter would give a mean height that had a standard error of less than two meters.

A grid of .02 random points per square meter at an average scale of 1:2000 was used. The variations in actual size of the icebergs resulted in variations of photographic scale. In all but a few cases, the number of random sample points exceeded the minimum density.

Change in Height Versus Change in Parallax

The stereo pairs used had no real reference level, since the sea surface had no detail in the photographs. Therefore, it was necessary to construct a linear relationship between the change in height (Δh) and the change in parallax (Δp) for each iceberg. To construct such a graph, points on the iceberg were chosen on the horizontal and oblique photographs and the actual heights of these points were computed. These same points were then located on the stereo pair and the parallax was measured. Using a least square fit to these points (four to eight for each iceberg), a ratio of Δh to Δp was established for each iceberg. This ratio was used to convert the iceberg's mean parallax ($\overline{\Delta p}$) to mean height ($\overline{\Delta h}$). By comparisons with actual height measurements we determined that the heights from the oblique photographs were more reliable than those from the horizontal photographs. This was because the only scale reference for the horizontal photography was the presence of the helicopter in the field of vision. Depth of field, orientation of the helicopter (e.g., level or not) and its position in relation to the plane of the icebergs were not constant or definable. The oblique mensurations on the other hand did not require a scale reference.

Therefore, we used only the oblique photography to determine the ratio of $\overline{\Delta h}$ to $\overline{\Delta p}$.

Oblique Mensurations

The principal point (P) is the center of the photographic format. A line drawn through (P) perpendicular to the visible horizon is the principal line (PH_1), the point of intersection being (H_1). The depression angle (θ_1) between the optical axis of the camera and the visible horizon is calculated:

$$\tan \theta_1 = PH_1/(f \cdot M)$$

where (f) is the focal length of the camera in milimeters and (M) is the enlargement factor of the photograph. The dip angle (D) between the visible horizon and the lens horizon is computed.

$$D = 9.03\sqrt{H}$$

where (H) is the flying height of the helicopter in meters. The depression angle (θ) between the optical axis of the camera and the lens horizon is found by $\theta = \theta_1 + D$. The distance (PH) measured along the principal line to the lens horizon is calculated:

$$PH = f \cdot \mathrm{Tan}\ \theta \cdot M$$

This distance is laid out along the principal line through point H_1 in the direction of the visible horizon. The lens horizon is then drawn perpendicular to the principal line through point (H). Heights, in meters, of selected points on the iceberg can be determined in relation to the lens horizon by using the following formula:

$$h = \frac{(K)(H)(a\text{-}b)}{a(K\text{-}b)}$$

where; (K) is a constant equal to:

$f/(\sin\theta \cdot \cos\theta)$

H = Flying height in meters.

a = Perpendicular distance from lens horizon to the water line, measured in millimeters.

b = Perpendicular distance from lens horizon to the top of selected points, measured in millimeters.

All angles are in degrees, and all photographic measurements are in millimeters.

Analysis

A stereo pair for each iceberg was set up with a random sampling grid. The parallax was measured to each point on the grid. The mean parallax for the iceberg was then determined using a simple average. This mean parallax (P) was converted to mean above water height (h) for the iceberg by using the ratio of h to p for each iceberg. The mean height multiplied by the sea level cross-sectional area of the iceberg, as determined on the a photo data quantitizer, then equalled the above water volume of the iceberg. The iceberg has a mean density of 0.8997 metric tons per cubic meter (Smith, 1931) and sea water in the area of study had a density between 1.024 and 1.027 g/cm³. The total volume, V_1 of the iceberg is given by

$$V = V_1 + V_2$$

where V_1 is the above water volume and V_2 is the below water volume. The mass, M, of the iceberg is then given by its total displacement

$$M = \rho_{sw} V_2$$

where ρ_{sw} is the density of sea water. The mass of the iceberg is also given by the expression

$$M = \rho_i V = \rho_i (V_1 + V_2)$$

where ρ_i is the density of glacial ice. Equating (2) and (3) gives

$$\rho_{sw} = \rho_i (V_1 + V_2)$$

solving for V_2 in terms of V, and using $\rho_i = .8997\ {}^{gm}/_{cm^3}$ and $\rho_{sw} = 1.0255\ {}^{gm}/_{cm^3}$ yields a result

$$V_2 = 7.15\ V_1$$

$$V = 8.15\ V_1$$

from (1) to (5). From equations (3) and (6), assuming a uniform density for the iceberg, the total mass metric tons of an iceberg is then 7.33 times the above water volume of the iceberg in cubic meters.

$$M = 7.33\ V_1$$

A least square analysis of V_1 as related to product of the longest side (L), shortest side (W), and the height of the highest point (H), indicates that

$$V_1 = .41\ LWH$$

combining (7) and (8) yields

$$M = 3.01\ LWH$$

The errors which contribute to the total error of iceberg mass measurements originate in the following ways.

a. The measurement of the heights of selected point on the berg has an error estimated at ±5%.

b. The parallax measurements using the stereocomparagraph have an error of ±2%.

c. Calculations of the mean berg height from heights taken at random points have an error of less than ±9% associated with it.

d. The waterline cross-sectional area can be measured by the optical image analyzer to within ±1%.

Combining the errors using a simple summation yields a total error of ±17% or less.

Results and Conclusions

The purpose of this study was to develop a technique for easily and quickly estimating the mass of an iceberg. Several relationships were tried such as separating bergs into visual shape classes, plotting height against berg mass, and using a combination of these two approaches. The correlation that appears to be most satisfactory both from the point of view of simplicity and also accuracy is the correlation between the product of the longest side, shortest side, and height of the highest point with the total mass of the iceberg. This approximates the above water portion of the berg with a rectangular box. If the length, width and height are measured in meters, then the total mass of the berg in metric tons is estimated to be 3.01 times the product.

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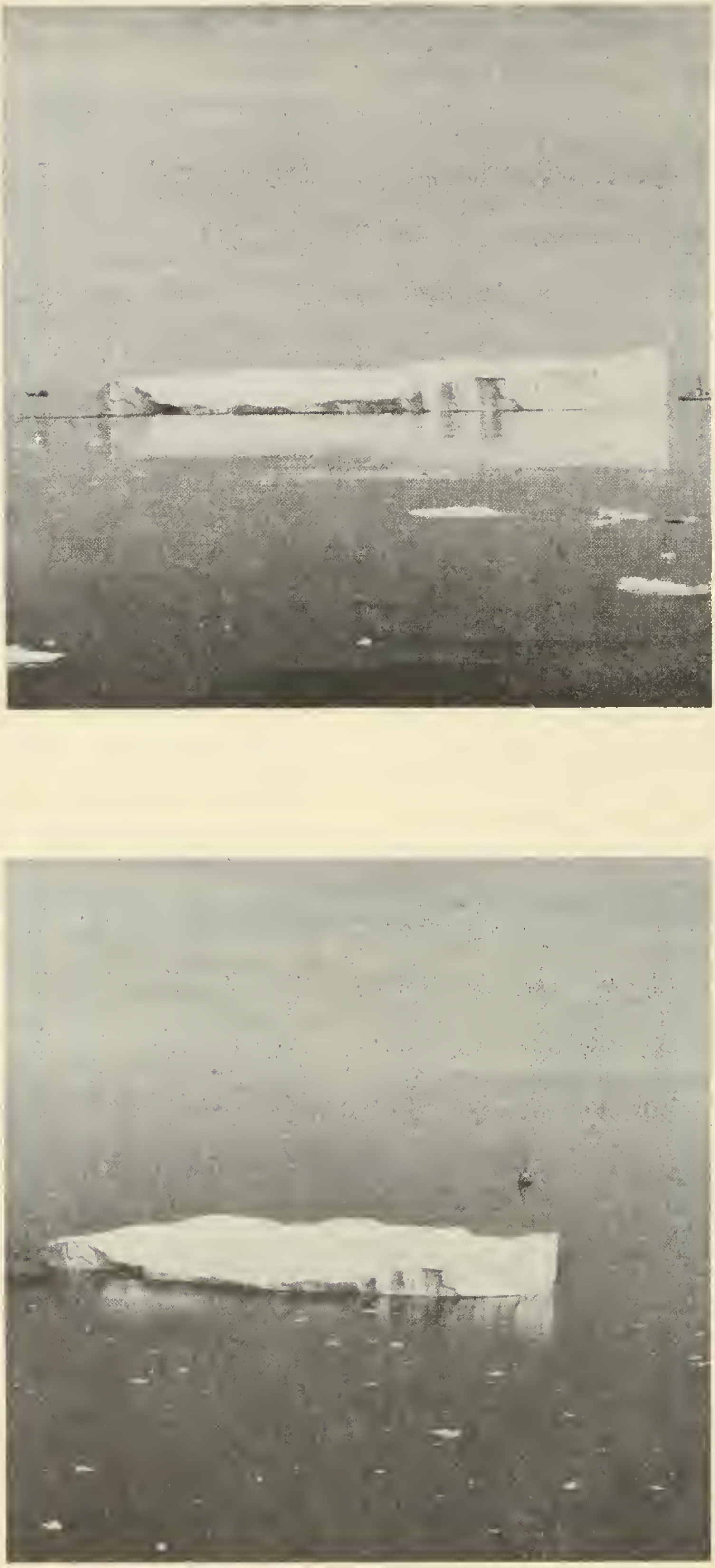


FIGURE D-2.—Horizontal (A) and Oblique (B) photographs of an iceberg

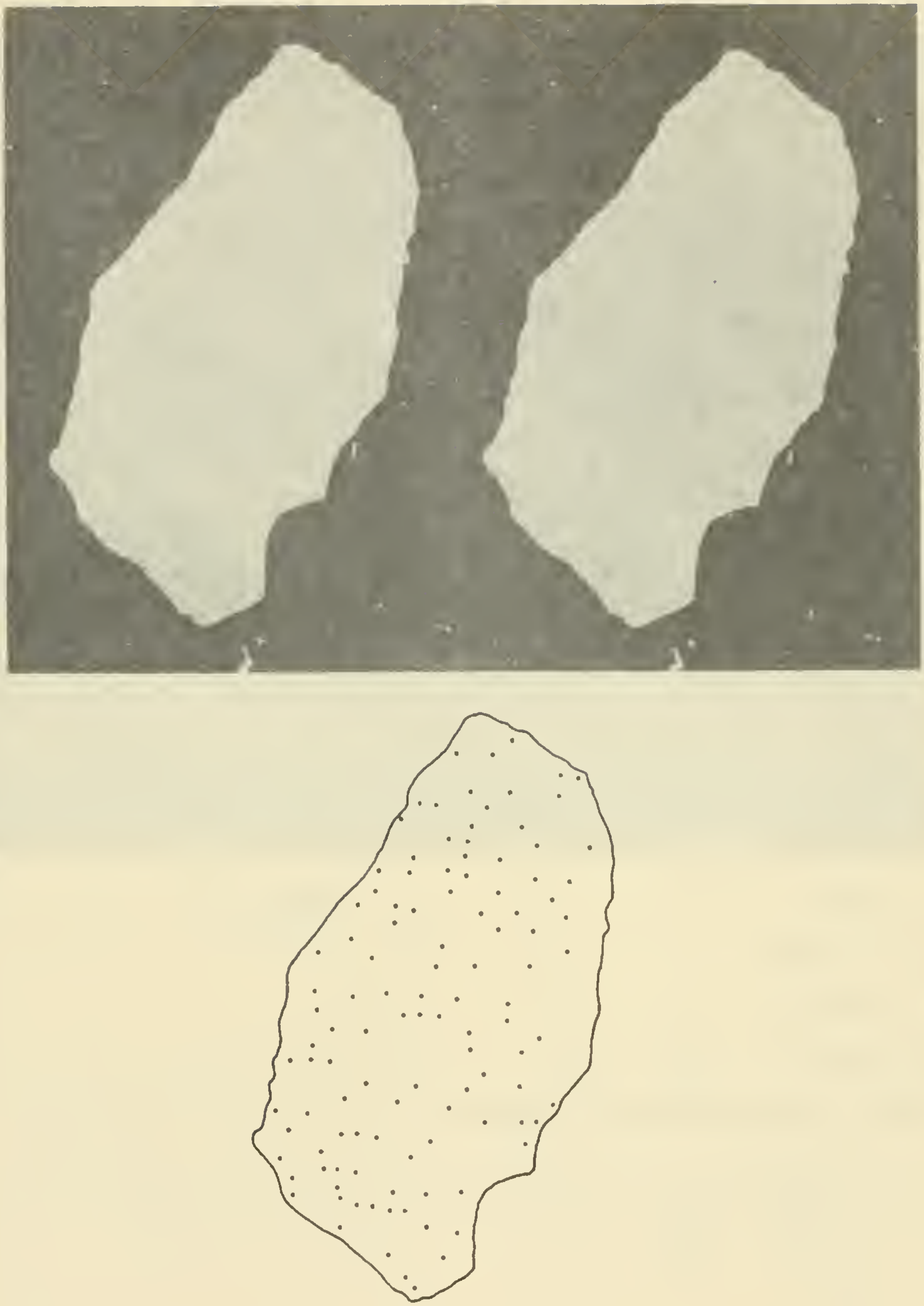
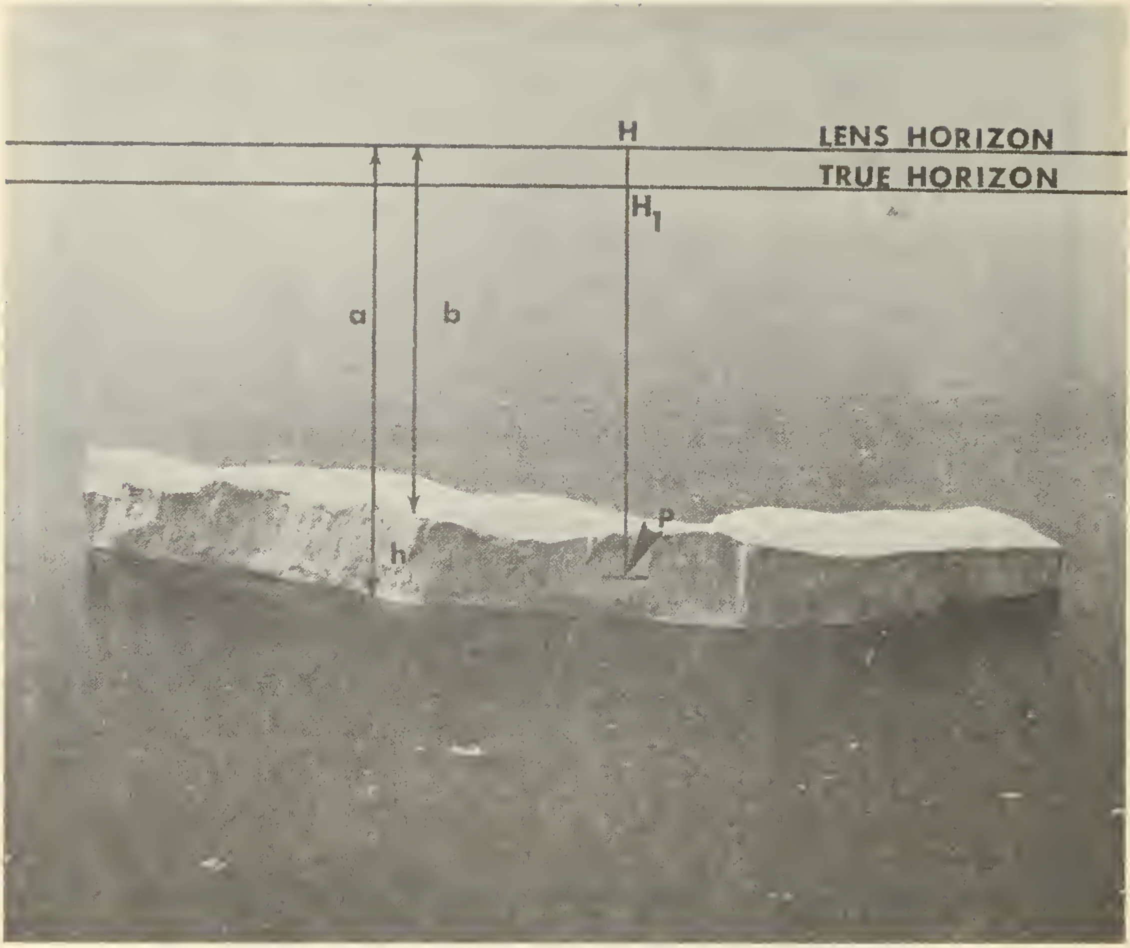


FIGURE D–3.—Examples of stereo pair (top) and random sample point (bottom)



$H = 152m$

$PH_1 = 55mm$

$f = 100mm$

$M = 3.5X$

$\tan \theta_1 = PH_1 / (f \cdot M) = .15714$

$\theta_1 = 8.93°$

$D = 0.03\sqrt{H} = .37°$

$\theta = 9.30°$

$PH = f \cdot \tan\theta \cdot M = 57mm$

$K = f/(\sin\theta \cdot \cos\theta) = 627$

$$h = \frac{(K)(H)(a-b)}{a(K-b)}$$

$h = 32m$

Figure D–4.—Oblique Mensurations

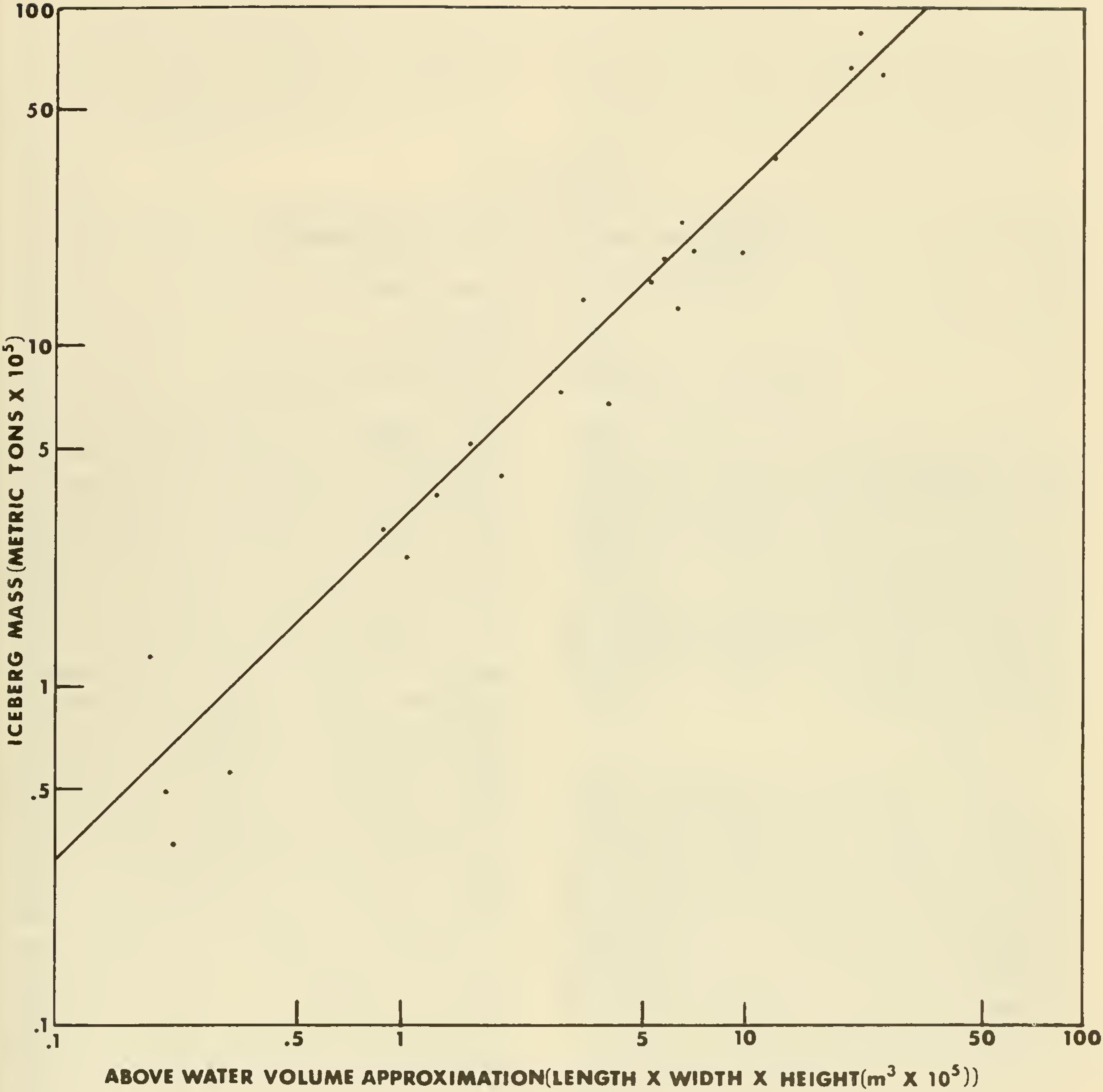


FIGURE D-5.—Least square fit of the above water volume approximation (height of highest point X long horizontal axis X narrow horizontal axis) versus the total calculated iceberg mass.

APPENDIX E

PHYSICAL PROPERTIES OF ICEBERGS

Height to Draft Ratios of Icebergs

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U.S. Coast Guard Research and Development Center

A study of height to draft ratios of icebergs near the Davis Strait reveals ratios which range from 1:1.28 to 1:10.56. The ratios of bergs dominated by their horizontal dimension average from 1:4.26 to 1:4.46. Bergs with a more vertical nature, such as pinnacle or drydock bergs, have ratios averaging from 1:2.31 to 1:2.41. The smallest ratios are found in domed bergs, which average 1:6.30. The highest berg studied was 59 meters high, and the berg with the greatest draft drew 161 meters.

Introduction

The draft of icebergs is of interest for a variety of reasons. In areas where pipelines or cables lie on the bottom, information on draft can be used to estimate the probability of a break. For the International Ice Patrol, the draft is of interest because of the effect it may have on drift, groundings and deterioration. Approximately seven eighths of the mass of an iceberg is submerged; however, this is not an indication that the height to draft ratio is necessarily 1:7.

Estimates of height to draft ratios were made as far back as the late 19th century. Steenstrup (1893) gives the ratio as 1:7.4 and 1:8.2; while Krummel (1907) gives a ratio between the extremes of 1:18 and 1:4, with most falling in the range of 1:5 and 1:6. Grounded icebergs were used to obtain the earliest estimates of the ratio. Dawson (1907) found a berg stranded in the Strait of Belle Isle in 1894 which had a ratio of 1:3. Again in the Strait of Belle Isle, Rodman (1890) found a 30-meter pinnacle berg grounded in 29 meters of water for a ratio of nearly 1:1. To estimate draft, Smith (1925) used a drag wire strung between two heavy weights and towed at known depths by two small boats. The small boats, separated by about 137 meters, would pass on opposite sides of the iceberg and lower the weights till the wire passes freely under the iceberg. He found a ratio of 1:2. During the 1959 ice patrol, Budinger (1960) examined the underside of an iceberg by diving under it. He found that the berg had a height to depth ratio of 1:3.3. Budinger also observed another berg 55 meters high grounded in 175 meters of water off Cape Race (ratio of 1:3.2). Budinger erroneously states that the height to depth ratio cannot be smaller than 1:6. This was in conflict with earlier estimates by Steenstrup (1890) and Krummel (1907) and also was not substantiated by data from the present study. Data collected by the submarine USS SEA DRAGON, which studied nine bergs, found height to draft ratios which ranged from 1:1.3 to 1:4.2 (Murray, 1960).

The height to draft ratio was highly dependent on the shape of the berg. The berg had to float so that seven eighths of its mass was submerged and so that the berg was stable. If, for instance, the iceberg was tabular (flat top and bottom and vertical side) a ratio of 1:7 would be expected. If the above-water portion was rounded and smooth, while the underwater part was pointed, then a ratio smaller than 1:7 could be expected, even as small as 1:9 or 1:10. The other extreme was the case where the underside of the berg was rounded and smooth and the above-water portion had towering vertical walls. The most pronounced case of this type was the drydock berg where an embayment had been cut out of the center of the berg leaving only a thin rim of great height and little mass. These could have a height to draft ratio which approached 1:1.

The purpose of this study was to see if the above water shape of icebergs was related in a significant way to the height to draft ratios for those bergs. Height to draft ratios were obtained for a total of 30 icebergs.

Methods

Measurements of iceberg draft were taken with a Kelvin-Hughes Transit Sonar during a cruise aboard the CGC EDISTO, July 1974. The EDISTO was operating in the Davis Straits area and along the west coast of Greenland. The Kelvin-Hughes Transit Sonar was designed to conduct bottom surveys; however, we were interested in vertical targets rather than in horizontal ones. The sonar transducer produced a beam .5° wide in the horizontal and 52° wide in the vertical, both being to the 3db level. For our purposes the transducer was pointed down by 26°, so that the top of the fan-shaped beam would just pass under the surface of the water and the bottom of the beam would be depressed at 52°. The transit sonar was designed for use from a small boat with only a few feet of freeboard. It was mounted on the EDISTO's arctic survey boat (ASB). This arrangement worked well, providing cover for the deck gear and personnel, along with high maneuverability and good speed control. The first five bergs were surveyed from the ASB with great success. Use of the ASB was then discontinued because the single point bridle used to raise and lower it was hazardous in any but the calmest weather. For the next two bergs the motor surf boat (MSB) was used. It was inadequate because the equipment was exposed to the weather and because the boat had such little stability that it was difficult to maintain the transducer orientation with respect to the iceberg. The MSB was retired due to a failure of the boat davit.

Finally, a method for using the transducer from the EDISTO itself was devised. The freeboard of the EDISTO was approximately eighteen feet from the rail to the water line aft of midship. A 21 foot pipe was fabricated that would support the transducer three feet below the water line. The transducer was mounted on the bottom of the pipe, and the pipe was manhandled from the deck to the outboard position for each run. Small chunks of ice were a constant problem and once sheared the transducer off the supporting pipe. A safety line attached to the transducer prevented loss of equipment. With the sonar on the EDISTO it was possible to have the deck gear in the oceanographic laboratory and also to operate from a very stable platform.

When the ship was positioned near enough to the berg, the beam of the sonar was completely intercepted by the iceberg. As the ship circled the berg, it increased the distance from the berg so that at some part of the sonar beam passed under the berg. The distance was increased till the ship was at maximum range (550 meters slant distance from the bottom of the berg) or a good echo was no longer received.

Five assumptions were made in interpreting the record. First, that the first echo was returned from the near surface portion of the berg; second, that the strong echos were reflected from vertical surfaces on the underwater portion of the berg; third, that weak returns came from walls which slope away from the observer along a radial of the sonar beam; fourth, that blank areas in the return were the results of shadow areas caused by caves, holes or ridges in the iceberg; and fifth, that if the transducer was far enough away from the berg the last return from the berg comes from the deepest portion of the berg.

The entire record of the iceberg sonar trace was examined and points which were representative of the deepest point on the berg were chosen. These points were plotted on radial grid so that the radial distances to the various portions of the berg could be converted to vertical measurements of berg draft. These estimates of draft were plotted versus distance to the berg. As the distance to the berg increased, the draft estimates approached an asymptote which was assumed to represent the true draft of the iceberg.

Discussion

The subaerial shapes of icebergs are extremely varied, sometimes displaying fantastic forms. Some bergs have "windows" in high vertical walls, while others are pockmarked like a piece of Swiss cheese, and still others have huge grottos or voids. As a means of organizing the shapes of the visible portion of icebergs into some system certain prominent characteristics have been chosen and used for typing icebergs into classes. These classes are based solely on visual identification.

This study examines whether or not the visual classification of icebergs is a meaningful way to classify the height to draft ratios of these bergs. Based loosely on Murray (1968), the icebergs of this study were separated into five general categories based on gross visual shape characteristics.

1. Tabular bergs were horizontal, flat-topped bergs with a length to height ratio generally greater than 5:1.

2. Broken tabular bergs were those that were mainly horizontal but whose surface was highly fractured, with a length to height ratio generally greater than 5:1.

3. Pinnacled bergs had a large central spire or a pyramid of one or more spires dominating the shape.

4. Domed bergs had a large, smooth rounded top which had once been submerged.

5. Drydocked bergs had an eroded U-shaped slot cut by wave action surrounded by high vertical walls or pinnacled.

The mean height to draft ratio for each of the five visual classes was computed and compared statistically to the mean ratio for all other classes. The null hypothesis is that there is no significant difference between the height to draft ratios for the visual classes of icebergs.

The height to draft ratios for the icebergs studied ranged from 1:1.28 to 1:10.56 (Tables 1 through 5). The 1:1.28 value was in line with previous measurements, but the 1:10.56 value was smaller than any of the previously reported ratios. The 1:10.56 ratio was associated with a domed berg where the rounded above-the-water portion had the maximum mass in the minimum height. To attain this value the underwater portion probably had a taproot-like formation.

The tabular and broken tabular (Tables 1 and 2) had almost identical characteristics. These were the most massive of the bergs, having lengths which were observed to reach 600 meters in this study and much larger in other studies. The mean heights for the tabular and broken tabular were 28.3 and 27.7 meters respectively; the mean drafts being 108.0 and 107.1 meters respectively. Of course, the height to draft ratios were quite similar also, being 1:4.46 for the tabular and 1:4.26 for the broken tabular. It appears that generally all bergs which were dominated by a horizontal dimension can be grouped together in respect to their draft ratios.

Table 1. Height to draft ratios for tabular bergs

	Height (meters)	*Depth (meters)*	*Ratio (1:)*
	35	122	3.48
	40	80	2.00
	30	137	4.57
	21	97	4.62
	32	84	2.62
	12	115	9.58
	28	121	4.32
Mean	28.3	108.0	4.46
S.D.	9.3	21.4	2.47

Table 2. Height to draft ratios for broken tabular bergs

	Height (meters)	*Depth (meters)*	*Ratio (1:)*
	41	139	3.39
	18	60	3.33
	13	94	7.23
	30	111	3.70
	55	161	2.93
	21	88	4.19
	20	126	6.30
	21	78	3.71
	30	107	3.57
Mean	27.7	107.1	4.26
S.D.	13.2	31.4	1.48

Pinnacle bergs (Table 3) and drydock bergs (Table 4) also appear to have been quite similar to each other. These bergs had great height with comparatively little mass. The average height to depth ratios for pinnacle bergs was 1:2.31 compared to 1:2.41 for drydock bergs.

Table 3. Height to draft ratios for pinnacle bergs

	Height (meters)	*Depth (meters)*	*Ratio (1:)*
	16	37	2.31
	59	111	1.88
	32	84	2.62
	34	83	2.44
Mean	35.2	78.8	2.31
S.D.	17.8	30.7	0.32

Table 4. Height to draft ratios for drydocked bergs

	Height (meters)	*Depth (meters)*	*Ratio (1:)*
	53	68	1.28
	44	103	2.34
	30	108	3.60
Mean	42.3	93.0	2.41
S.D.	11.6	21.7	1.16

Domed bergs (weathered, smoothed, deteriorated bergs) were the most deceptive (Table 5). They penetrated the water's depths as the pinnacle bergs penetrated the air. The domed bergs had an average height to depth ratio of 1:6.30, by far the smallest ratio of any class of bergs.

Table 5. Height to draft ratios for domed bergs

	Height (meters)	*Depth (meters)*	*Ratio (1:)*
	30	79	2.63
	16	52	3.25
	12	65	5.42
	21	157	7.48
	13	92	7.07
	9	95	10.56
	12	92	7.67
Mean	16.1	90.3	6.30
S.D.	7.2	33.4	2.76

Conclusion

The assumption was made that the height to draft ratios of icebergs form a continuous distribution. Using a Kruskal-Wallis one-way analysis of variance technique, Welch (1975), the hypothesis that the average ratio for icebergs was not significantly different for the gross visual shape classes was tested. This resulted in the conclusion that, for the sampled icebergs, there was no significant difference between classes. For summary purposes the average of the visual class averages (1:3.95) can be used as descriptive of the height to draft ratio of icebergs regardless of visual shape classes.

Since one visual class was not significantly different from another with respect to the height to draft ratio, all classes were combined and the ratios were plotted against iceberg height. The distribution was by no means linear and was best represented by the power curve (See Figure E-3).

$$1/\text{ratio} = 49.4\ (\text{Height})^{-.8}$$

The taller bergs had a narrower range of height to draft ratios than the lower bergs, which had height to draft ratios which spanned the entire range. Icebergs with the greatest height had the largest height to draft ratios. The draft for tall icebergs was proportionally less than for low bergs. The reasons for this were conjectured to be as follows:

a. The tallest bergs generally had spires and pinnacles which add great height with minimum mass, while the lowest bergs tend to be worn and smooth, having maximum mass for minimum heights.

b. The lowest bergs were worn and have only the most dense ice remaining, all unconsolidated ice and snow having been washed away, and most voids having disappeared causing them to float lower in the water.

The height to draft ratios measured in this study fall generally into three groupings: the horizontal berg, the vertical berg, and the weathered berg. The ratios are smaller (greater depth for a given height) than have been presented in recent work on icebergs. The domed berg has a surprisingly large draft, which must indicate that the underwater portion is not rounded as the top. With these results it will be possible to develop a better model of exactly what water layer is acting on an iceberg during drift and deterioration studies.

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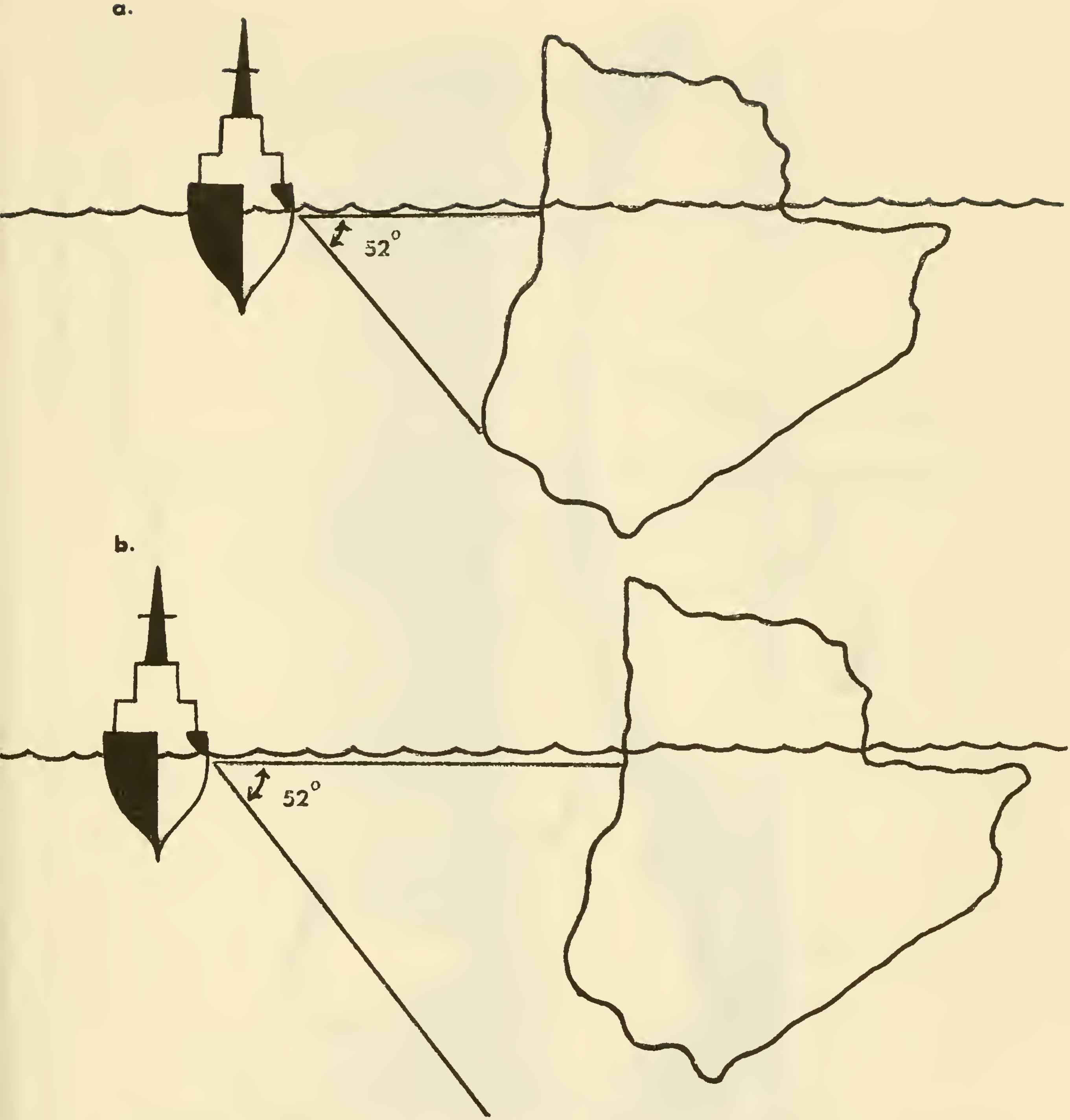

FIGURE E–1.—(a) The beam from a side-looking sonar is completely intercepted by the iceberg at very close range; (b) at great range a portion of the sonar beam will pass under the iceberg and not return to the transducer.

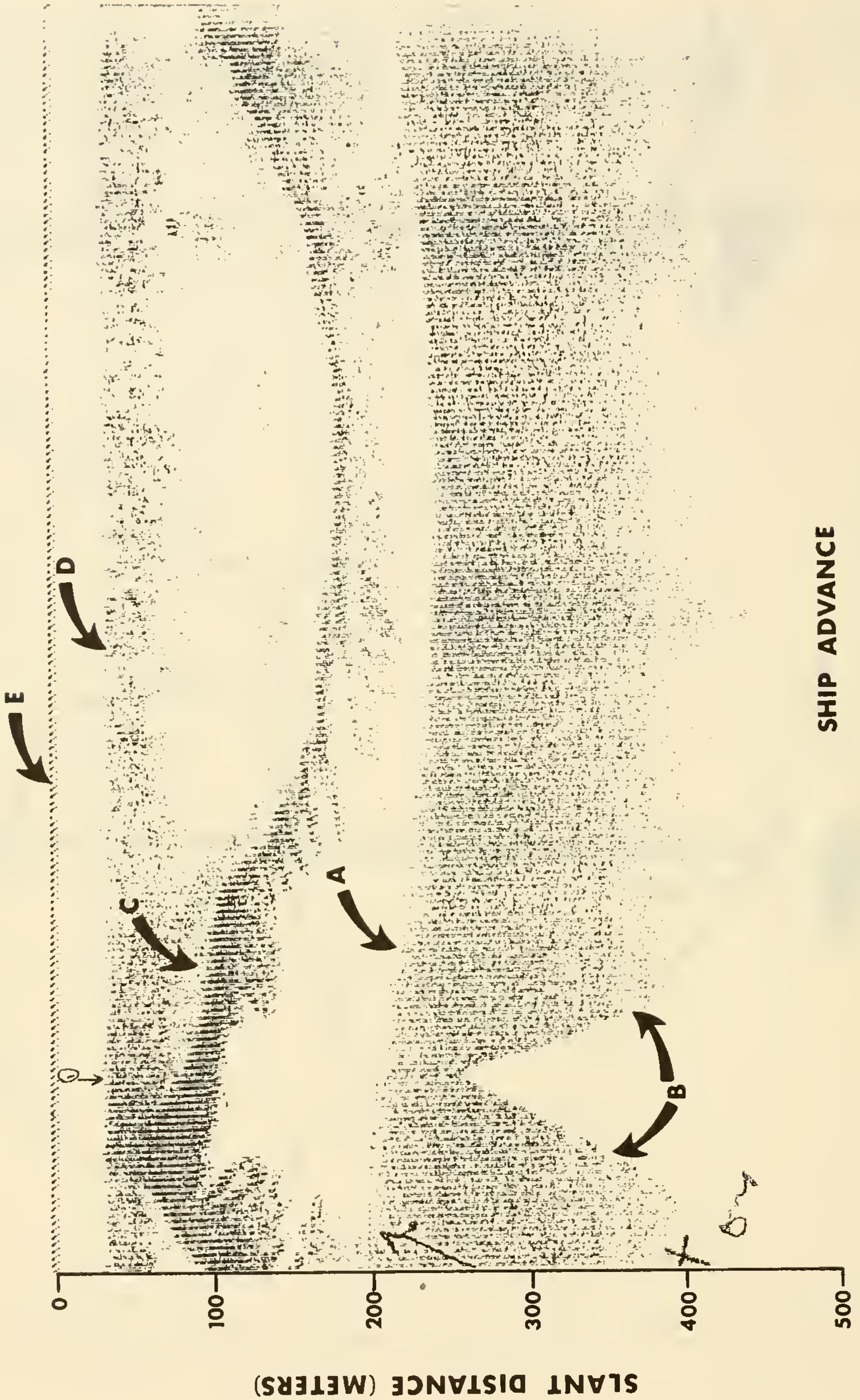

FIGURE E–2.—A sample of the side-looking sonar record showing; (A) the return from the bottom, (B) the shadow of the iceberg on the bottom giving an approximate shape, (C) the return from the iceberg, (D) the return from waves, (E) the zero line on the chart.

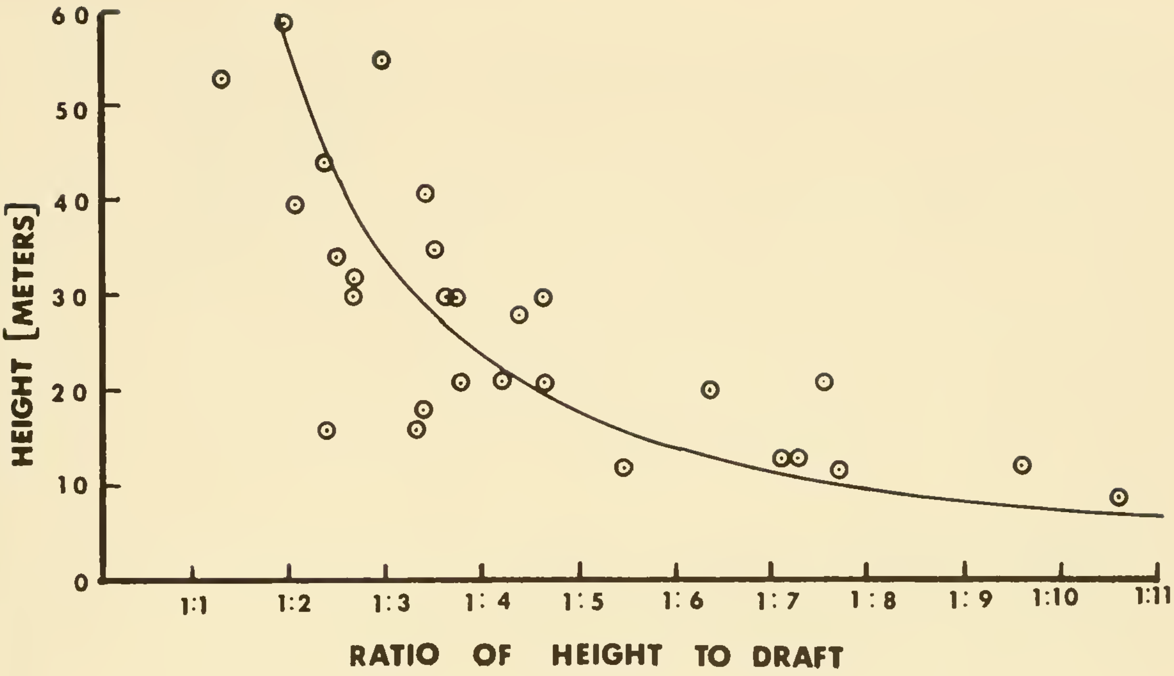

FIGURE E-3.—The distribution of height to draft ratios of icebergs as a function of iceberg height.

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Bulletin No. 62

REPORT OF THE INTERNATIONAL ICE PATROL SERVICE IN THE NORTH ATLANTIC OCEAN

Season of 1976

CG-188-31

FOREWORD

Forwarded herewith is Bulletin No. 62 of the International Ice Patrol describing the Patrol's services, and ice observations and conditions during the 1976 season.

N. C. VENZKE
Chief, Office of Operations

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PREFACE

This report is the 62nd in a series of annual reports on the International Ice Patrol Service in the North Atlantic Ocean. It contains information on Ice Patrol organization, communications and operations, on ice and environmental conditions and their interaction as observed during 1976, and on various Ice Patrol research efforts.

The authors of this report, Lieutenant H. Gregory KETCHEN, USCG and Marine Science Technician First Class Charles W. JENNINGS, USCG acknowledge the Canadian Department of the Environment for providing ice and weather information, the United States Weather service for weather updates, the United States Naval Weather Service for both weather and oceanographic products, and the United States Coast Guard Oceanographic Unit and Cutter EVERGREEN for oceanographic data collected during the course of the ice season. Acknowledgement is also made to Yeoman Second Class Terry L. GEST, USCG and Marine Science Technician Chief Neil O. TIBAYAN, USCG for their assistance in the typing and preparation of the majority of illustrations in this report.

INTERNATIONAL ICE PATROL, 1976

The 1976 International Ice Patrol Service in the North Atlantic Ocean was conducted by the personnel and with the facilities of the United States Coast Guard under the provisions of Title 46, United States Code, Sections 738, 738a through 738d and the International Convention for the Safety of Life at Sea, 1960, Regulations 5 through 8. The International Ice Patrol provides a service that observes and disseminates information on ice conditions in the Grand Banks Region of the Northwest Atlantic Ocean. During the ice season, the southeastern, southern and southwestern limits of the regions of icebergs in the vicinity of the Grand Banks of Newfoundland are guarded for the purpose of informing passing ships of the extent of this dangerous region. The International Ice Patrol also studies ice conditions in general with emphasis on the formation, drift and deterioration of icebergs, and assists ships and personnel requiring aid within the limits of operation of the Ice Patrol forces.

The International Ice Patrol is directed from the Ice Patrol Office located at the U.S. Coast Guard Base, Governors Island, New York. The Office gathers ice and environmental data from a variety of sources, maintains an ice plot, forecasts ice condition, prepares the twice-daily Ice Bulletin, replies to requests for special ice information, and executes operational control of the Aerial Ice Reconnaissance Detachment, the Ice Patrol oceanographic cutter(s), and the Surface Patrol cutter(s) when assigned.

Vice Admiral William F. REA, U.S. Coast Guard, was Commander, International Ice Patrol. Commander Albert D. SUPER, U.S. Coast Guard, was the Ice Patrol Officer and as such directly responsible for the management of the Patrol.

There were two preseason reconnaissance missions conducted during the periods 22 January to 1 February and 25 February to 10 March 1976. The Aerial Ice Reconnaissance Detachment was deployed to St. John's, Newfoundland, Canada on 18 March 1976 and returned to the United States on 22 July 1976.

The 1976 Ice Season officially commenced at 0000 GMT on 18 March, when the first Ice Bulletin was issued, and continued until the final Bulletin was issued at 0000 GMT 22 July 1976. Daily facsimile charts and twice-daily Ice Bulletins were prepared by the International Ice Patrol and broadcast as discussed in the communications section of this report. Iceberg information was also included on the regularly scheduled radio facsimile broadcasts made by the Navy Weather Central Norfolk/NFAX, Maritime Command Radio Halifax/CFH, Radio Bracknell/GFE, Radio Hamburg-Quickborn/DGC and Radio Quickborn/DGN.

The U.S. Coast Guard Cutter EVERGREEN, commanded by Lieutenant Commander Joseph H. DISCENZA, U.S. Coast Guard conducted oceanographic cruises for the Ice Patrol from 23 March to 25 April and 18 May to 01 July. Additionally, the U.S. Coast Guard Cutter SHERMAN, commanded by Captain Howard M. VEILLETTE conducted a special Ice Patrol oceanographic cruise slightly east of the Grand Banks from 08 June–01 July 1976. All these cruises provided vital ocean current and temperature data used as inputs to the computerized iceberg drift program and iceberg deterioration predictions. Ice Patrol oceanographic activities are discussed further in the Oceanographic Conditions section of this report.

For the third consecutive year no surface patrol was required to patrol the southern limits of icebergs.

During the 1976 Season an estimated 151 icebergs drifted south of 48° North latitude, a light season that had a total duration of 126 days.

AERIAL ICE RECONNAISSANCE

During the period 22 January 1976 to 22 July 1976, a total of 75 ice observation flights were flown. Preseason flights made in January and February accounted for 14 flights, and the remaining 61 flights were made during the ice season. There were no post-season flights. The purpose of the preseason surveys was to determine the inventory of icebergs in the western Labrador Sea and Davis Straits for use in an attempt to predict the severity of the 1976 ice season. The objectives of the regular season flights were to locate the southwestern, southern, and southeastern limits of icebergs, to determine the iceberg population north of these limits in the vicinity of the Grand Banks and occasionally along the Labrador Coast, and to determine sea surface temperatures along search tracks using an airborne radiation thermometer. In addition to this routine reconnaissance flights, there were 10 flights conducted solely for the purpose of testing and evaluating a Side-Looking Airborne Radar (SLAR) System. It is anticipated that this system will become an invaluable tool to the Ice Patrol for the all weather detection and identification of icebergs.

Table 1—Aerial Ice Reconnaissance Statistics September 1975 to August 1976

Month	*Number of Flights*	*Flight Hours*
PRESEASON		
September-December	0	0
January	4	25.8
February	3	14.2
March	7	40.7
Preseason total	14	80.7
SEASON		
March	5	28.8
April	11	59.2
May	19	100.8
June	14	74.6
July	15	68.1
August	0	0
Season total	64	331.5
Remote Sensing Test and Evaluation		
April	0	0
May	9	43.8
June	1	6.8
July	0	0
T&E total	10	50.6
Season total	74	382.1
Annual total	88	462.8

In addition, 51 missions and 216.1 flight hours were employed in penetrometer tagging R&D, a media-public affairs reconnaissance deployment, special parts/logistics support deployments, and periodic flights between St. John's and the United States necessary for crew relief and aircraft maintenance.

Aerial ice reconnaissance was accomplished by U.S. Coast Guard HC–130 (Lockheed Hercules) four-engine aircraft from the Coast Guard Air Station in Elizabeth City, North Carolina. The aircraft used on Ice Patrol were outfitted with inertial navigation systems (INS) with position accuracy of better than ±5 nautical miles. During the iceberg season, the aircraft operated out of Innotech Aviation at Torbay Airport, St. John's, Newfoundland.

COMMUNICATIONS

Ice Patrol communications included receiving reports of ice, sea surface temperature, and other environmental conditions, transmitting twice-daily Ice Bulletins and a daily facsimile chart, and the administrative and operational traffic necessary to the proper conduct of the Patrol. The Ice Bulletin was transmitted by teletype from the Ice Patrol office in New York twice each day to our 30 addresses, including those radio stations which broadcast the Bulletin. These stations were U.S. Coast Guard Communications Station Boston/NMF/NIK, Canadian Coast Guard Radio Station St. John's/VON, Canadian Forces Maritime Command Radio Station Mill Cove/CFH, and on the U.S. Navy LCMP Broadcasts from Norfolk, Virginia; Londonderry, Northern Ireland; Thurso, Scotland; and Keflavik, Iceland. The daily radiofacsimile ice chart was broadcast from the Ice Patrol offices in New York via a transmission line direct to transmitters at U.S. Coast Guard Communications Station Boston/NIK.

Coast Guard Communications Station Boston transmitted the Bulletin by CW (Morse Code). A 2-minute series of test signals, the transmissions were made at 25 words per minute and then repeated at 15 words per minute. Table 2 lists frequencies and times of broadcasts used at the various radio stations for the Ice Patrol Bulletin:

Radio Station	Time of Broadcast (GMT)	Frequencies (kHz)
CW Broadcasts:		
Coast Guard Communications Station Boston/NIK	0018 1218	5320, 8502. 8502, 12780.
Coastal Radio St John's/VON	0000 and 1330	478.
Maritime Command Radio Mill Cove/CFH	0130 and 1330	438 (off second Thursday each month from 1200-1600 GMT), 4255, 6430, 12990, 16926.5 and 22397.5.
Naval COMMSTA Londonderry (LCMP BCST) Naval COMMSTA Iceland Naval COMMSTA Norfolk	0500 and 1700	5870, 8090, 12135, 16180, 20225, 25590 (Note: 20225 and 25590 activated only 1200-2400 (GMT)
Radiofacsimile Broadcasts:		
Coast Guard Communications Station Boston/NIK	1600	8502, 12750 (drum speed 120)
Fleet Weather Central Norfolk (NFAX)	0605 and 1805	3357, (0001-1200 GMT), 4975, 8080, 10865, 16410 (1200-2400 GMT), and 20015 (Limits of all known ice on nephanalysis.)
CANMARCOM/CFH	0000 and 1200	4271, 9890, 13510, 17560 (drum speed 120). (Primarily sea ice in Gulf of St. Lawrence and North Limits of icebergs sometimes given.)
Radio Bracknell/GFE	1400	4782, 9203, 14436, or 18261 (drum speed 120)(N Atlantic Ice Obs)
Radio Hamburg-Quickborn/Pinneburg/DGC, DGN	0905 (Except Sundays and Holidays) and 2145	3695.8 (0905-1014 GMT) and 13627.1 (2108-2157 GMT) (drum speed 120). (Ice Conditions in West Atlantic.)
Special Broadcasts		
Coastal Radio St Johns/VON	As required when icebergs are sighted outside the limits of ice between regularly scheduled broadcasts	Preceded by International Safety Signal (TTT) on 500 kHz

TABLE 2

Special broadcasts were made by Canadian Coast Guard Radio Station St. John's/VON and U.S. Coast Guard Communications Station Boston/NIK as required when icebergs were sighted outside the limits of ice between regularly scheduled broadcasts. These transmissions were preceded by the international safety signal (TTT) on 500 kHz.

Merchant ships calling to report ice sightings, weather and sea surface temperature to the Ice Patrol were requested to contact U.S. Coast Guard Communication Stations, Ocean Weather Station C7H and, if unable to work these stations, Canadian Coast Guard Radio Station St. John's/VON. These ships were requested to use the regularly assigned international call sign of the station being called; however, Coast Guard stations were alerted to answer NIK or NIDK calls if used.

Ice information services for the Gulf of St. Lawrence, as well as the approaches and coastal waters of Newfoundland and Labrador, were provided by the Canadian Ministry of Transport from December until approximately late June. Ships obtained ice information by contacting Ice

Operations Officer, Dartmouth, Nova Scotia via any east coast Canadian Coast Guard Radio Station.

Communications Statistics for the period 1 September 1975 to 31 August 1976 are shown below in Table 3.

TABLE 3—Communications Statistics

Number of ice reports received from ships	312
Number of ships furnishing ice reports	87
Number of ice reports received from commercial aircraft	2
Number of sea surface temperature reports	1,813
Number of ships furnishing sea surface temperature reports	47
Number of ships requesting special ice information	3
Number of NIK Ice Bulletins issued	253
Number of NIK facsimile broadcasts	126

Of the ships furnishing Ice Patrol with special sea surface temperature observations, the eight most outstanding contributors were:

M/V BAKKAFOSS/TFXQ

M/V ATLANTIC SPAN/SLPN (5th consecutive year)

M/V ESKDALEGATE/GUIC

M/V MONTROYAL/SFHN

HMCS NIPIGON/CGZP

M/V C P TRADER/GNAR

M/V MANCHESTER CONCORDE/GYUX

M/V BRUNSWICK/DGBI

ICE CONDITIONS, 1976 SEASON

September-December, 1975

After the close of the 1975 Ice Patrol Season, occasional icebergs continued to drift south along the Labrador coast, but none of these survived long enough to reach the primary North Atlantic shipping lanes. Ice reports received during the latter part of September included the sighting of a concentration of icebergs along a line from 53°N, 52°W to 51°N, 49°W. During this same period, a Canadian ice reconnaissance aircraft reported sighting a total of 117 icebergs and 135 growlers along the north side of Hudson Strait between Resolute Island and Big Island. On 26 September, two icebergs were sighted drifting together in an anomalous area (i.e., 53°06′N, 41°40′W). This location is far from the normal iceberg limit. These bergs were apparently the remaining pieces of one or possibly two large icebergs forced east out of the mainstream off Labrador by strong offshore winds that persisted over this area from mid-July through September. On September 27, a group of three icebergs was sighted in the vicinity of 50°54′N, 53°24′W. This was the last ice received until late October. Between mid-August and mid-October the eastern Canadian waters remained free of sea ice from the Baffin Island coast southward. Several iceberg reports were received from merchant shipping in the latter part of October. The southernmost of these was a medium size iceberg in position 50°45′N, 54°05′W on October 31. Freeze-up started in northern Baffin Bay during October and advanced to 68°N by the end of the month. On November 19, aircraft returning from Europe at high altitude reported a very large iceberg, estimated to have a horizontal area of approximately 3 square miles. This sighting was not confirmed and could possibly have been a small very dense fog patch. This was the only berg report for the month. During December, sea ice cover grew rapidly, expanding from the northern tip of Labrador in the beginning of the month to reach Newfoundland's northern peninsula by month's end. This pushed season freeze-up approximately one week to ten days ahead of normal. New ice was beginning to form in some of the sheltered shallows of Notre Dame Bay and the northern Newfoundland peninsula. Fast ice had formed along the entire east coast of Labrador and close pack new and grey ice from this area drifted southward across the eastern approaches to the Strait of Belle Isle. Reports of ice from trans-Atlantic shipping proceedings through the Strait of Belle Isle during December indicated a few icebergs were beginning to drift into this area.

January 1976

A Canadian forces aircraft reported three icebergs (no size indicated) at position 53°25′N, 52°33′W on 27 January. This was the only report during the month. After a brief warming trend at the beginning of the month, very cold air persisted over the Canadian Atlantic provinces until mid-January. As a result, there was widespread growth of new ice northeast of Newfoundland. Between 25 and 31 January, preseason flights were made along the Labrador coast, across Davis Strait and up the Baffin Island coast to Cape Dyer (Figure 1). The latitudinal iceberg distribution observed during these flights is illustrated graphically in figure 2. The count north of Hudson Strait in the survey area was 516, about 80% of the previous 10 year average. The iceberg inventory south of Hudson Strait was 42 or 55% of the average. The icebergs sighted were generally smaller than normal. The southernmost of these were one medium and two small bergs first sighted on 25 January in the vicinity of 53°51′N. These were resighted on 31 January in positions 53°21′N, 51°16′W and 53°18′N, 51°40′W. Strong winds and above normal temperatures during the last half of January retarded the southward drift of the sea ice pack off Labrador, causing it to expand seaward and to maintain generally light ice conditions in Notre Dame Bay. By the end of January, the sea ice

cover had advanced to a southern limit approximately by a line from 61°N 60°W southeasterly to 51°30′N, 50°W then southeasterly to Notre Dame Bay.

February 1976

With the southernmost icebergs still well north of the major shipping lanes, only one report was received from merchant shipping in February. Although this report of a small iceberg in position 51°10′N, 46°20′W on February 22 was the southernmost for the month, the iceberg limit established in early March indicated that bergs had reached at least 50°N by the end of February. Cold and persistent northwesterly winds across Davis Strait and in the northern Labrador Sea resulted in an abnormally extensive ice cover in this area. The heavier sea ice served to better protect those icebergs that would be reaching the Grand Banks late in the season. Off Newfoundland, the windflow continued to spread pack ice eastward, extending to nearly 49°W between 50° and 51°W by mid month. By month's end, the ice pack reached some 200 miles east of St. John's and south to 46°45′N. To the southwest of Newfoundland, pack ice was flowing out of the Gulf of St. Lawrence through the Cabot Strait and had extended approximately 100 miles east of Sydney.

March 1976

The second series of preseason flights were completed between February 27 and March 10. Tracks flown and icebergs observed during these reconnaissance flights are shown in figure 3. The latitudinal distribution of observed icebergs is displayed graphically in figure 4. When adjusted for poor visual and radar coverage in certain areas due to adverse weather, these counts represent roughly 50% of the normal upstream iceberg population for that time of year. As in January, the icebergs were predominantly small or medium sized with only a few large bergs observed. A total of 98 medium and large size icebergs were sighted between 55°N and 65°N. The southernmost iceberg spotted was a small tabular at 47°45′N, 46°00′W, which was predicted to have crossed 48°N on 9 March and was the first iceberg to reach that latitude in 1976. By mid-March, new and grey ice predominated in the coastal waters from Cape St. Francis northward. The heavy pack ice was east of Belle Isle and 60 miles east of Capes Freel and St. Francis. The eastern limit of ice had almost reached Flemish Cap. On approximately 12 March, the sea ice reached its southernmost extent for 1976 at latitude 45°55′N southeast of Cape Race. Based on predicted southward drifts of icebergs observed during the second preseason flight, the Ice Reconnaissance Detachment deployed to St. John's and the Ice Patrol season officially commenced on 18 March. Flights on 23, 24 and 27 March (Figure 5) established the southern and eastern limits of icebergs and growlers in the vicinity of the Grand Banks. It was estimated that 33 icebergs crossed 48°N during March. Although this equals the 30 year average for March, the predominant drift for the month was toward the east between 47°N and 50°N. All of the bergs that crossed 48°N during the month were predicted to have melted before reaching 47°30′N. The southernmost sighting was a small tabular at 47°45′N, 46°00′W on 10 March and the easternmost iceberg for both the month and the season was a small drydock sighted in position 48°16′N, 42°37′W on 24 March.

April 1976

During latter March and early April, mild weather caused the melt of the light ice which had made up the major ice cover along Newfoundland's east coast. This resulted in a pronounced northward retreat of the ice edge. By April 5 (Figure 6), the concentrated pack had retreated north of 50°N and west of 50°W with diffuse pack extending south to 48°20′N and east to 48°W. Aerial reconnaissance on April 12, 13 and 15 (Figure 7) located only one berg and three radar targets south of 49°N. To commemorate the 64th anniversary of the tragic loss of the RMS TITANTIC on April 15th, members of the International Ice Patrol dropped a memorial wreath near an iceberg on the Grand Banks. By mid-month, the southern limit of the pack ice was near 51°N with its eastern extension ending near 49°W. Although a few strips and patches of first year ice lay just off the North Peninsula coast and northern White Bay, the remainder of the Newfoundland east coast was essentially free of sea ice. Near the end of the month, prevailing northerly winds brought patches of ice into Notre Dame Bay, but in the process considerably reduced the seaward extent of the ice pack. These same winds brought a

very large grouping of icebergs into the core of the Labrador Current north of the Banks. Some 96 icebergs and 57 growlers were sighted between 48°30′N and 50°20′N during reconnaissance flights on April 18, 20 and 23 (Figure 8). These bergs were apparently east of the reconnaissance tracks flown during the second preseason mission. Some were sighted during early March flights (Figure 3), but most were east of visual and radar coverage and outside the sea ice, between 56°N and 59°N. In hindsight, it appears that these bergs were blown some 90 to 100 miles off the Labrador coast in late February just before the reconnaissance flights and then blown back into the protection of the sea ice during early March after the preseason tracks were flown. It was estimated that only 13 icebergs crossed 48°N during April. The southernmost of these was a medium size blocky sighted on April 4 at 46°24′N, 46°09′W, and the easternmost was a small dome on 4 April in position 48°47′N, 44°08′W.

May 1976

Flights on April 30 and May 1 and 2 located a heavy concentration of icebergs off the northeast corner of the Grand Banks extending southeastward to Flemish Cap (Figure 10). These bergs, plus some drifting in from the north, were resighted during flights on May 6, 8, 10, 12, and 13 (Figures 11 and 12). Due to prevailing westerly winds, they had drifted east passing north of Flemish Cap. The easternmost iceberg for the month was a medium drydock sighted on May 10 in position 48°07′N, 43°27′W. On 24 May a growler was sighted further east at 46°37′N, 43°17′ W(Figure 14). By mid-May, an open water route existed through the Strait of Belle Isle. Very open to close pack first year ice extended southward to about 51°N but remained approximately 30 miles east of Newfoundland's Northern Peninsula. The southernmost iceberg of the month was sighted with two other bergs and three growlers on May 30 at 44°10′N, 48°49′W. An estimated 67 icebergs crossed 48°N during May.

June 1976

Observation flights on May 31 and June 5 and 6 (Figure 15) revealed a diminishing iceberg population. Small groups of bergs and growlers were observed scattered just north of the Banks and east to Flemish Cap and others along 45°N east of the Banks. In June, warming air and sea temperatures brought a rapid disintegration of both pack ice and icebergs. By mid-June there was no sea ice south of 52°N. Flights on June 12 and 14 located only 17 icebergs and 12 growlers, none east of 46°30′W or south of 44°30′N (Figure 17). By June 22, those bergs off the northeast corner of the Grand Banks had drifted south to between 45°20′N and 46°20′N. One iceberg surviving from the group sighted east of the Banks on June 14 had drifted to a position slightly southeast of Flemish Cap by June 23 (Figure 19). All these icebergs had undergone extensive deterioration since their previous sighting. On June 29 the passenger liner Queen Elizabeth II spotted two groups of growlers, one at 43°30′N, 48°38′W and one at 43°30′N, 48°36′W. Two other merchant ships reported four icebergs and a number of growlers on the same day about 25 miles north of the QEII sightings. Predicted positions of this ice are shown in figure 20. This was the same ice that was spotted on June 22 (Figure 19) but was in final stages of decay. These reports were the southernmost for the month. Also on 29 June, a TWA flight returning from Europe spotted a medium sized berg at 46°36′N, 43°22′W. An estimated 35 icebergs crossed 48°N during the month.

July 1976

Flights on July 8 (Figure 21) spotted a small iceberg with a growler at 43°41′N, 48°58′W. This was believed to be the last ice presenting any danger to trans-Atlantic shipping during 1976. These two pieces of ice were resighted again by a merchant vessel on July 12 in position 42°28′N, 48°39′W. This was the southernmost ice sighting reported in 1976. Heavy fog persisted over the Grand Banks for most of July. Although the iceberg at the Tail of the Banks was predicted to have melted by July 15, this could not be visually confirmed due to the fog and the season was continued for an additional week. On July 22, feeling confident that the southernmost iceberg had totally melted, Ice Patrol advised the maritime community that there were no known icebergs south of 49°N and none expected to drift south of 47°N during the remainder of 1976. Ice Patrol services were terminated and the Ice Reconnaissance Detachment returned from St. John's on that date.

August 1976

No more icebergs were known to have drifted south of 48°N during August. The total count of icebergs crossing 48°N for the 1976 Season was 151. Although a number of sightings continued to be reported to the Ice Patrol during the month, all reports were located in the waters off Labrador. During August the only sea ice known to exist was off Baffin Island north of 62°N.

ESTIMATED NUMBER OF ICEBERGS SOUTH OF LATITUDE 48N, SEASON 1976

	Sept	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Total*
1976	0	0	0	0	0	0	33	13	67	35	3	0	151
TOTAL 1946–1976	10	2	4	11	64	261	1068	2939	2897	1751	483	100	9,590
AVERAGE 1946–1976	0	0	0	0	2	8	34	95	93	56	16	3	309
TOTAL 1900–1976	256	109	110	91	184	712	3170	7784	9980	5269	1679	489	29,833
AVERAGE 1900–1976	3	1	1	1	2	9	41	101	130	68	22	6	387

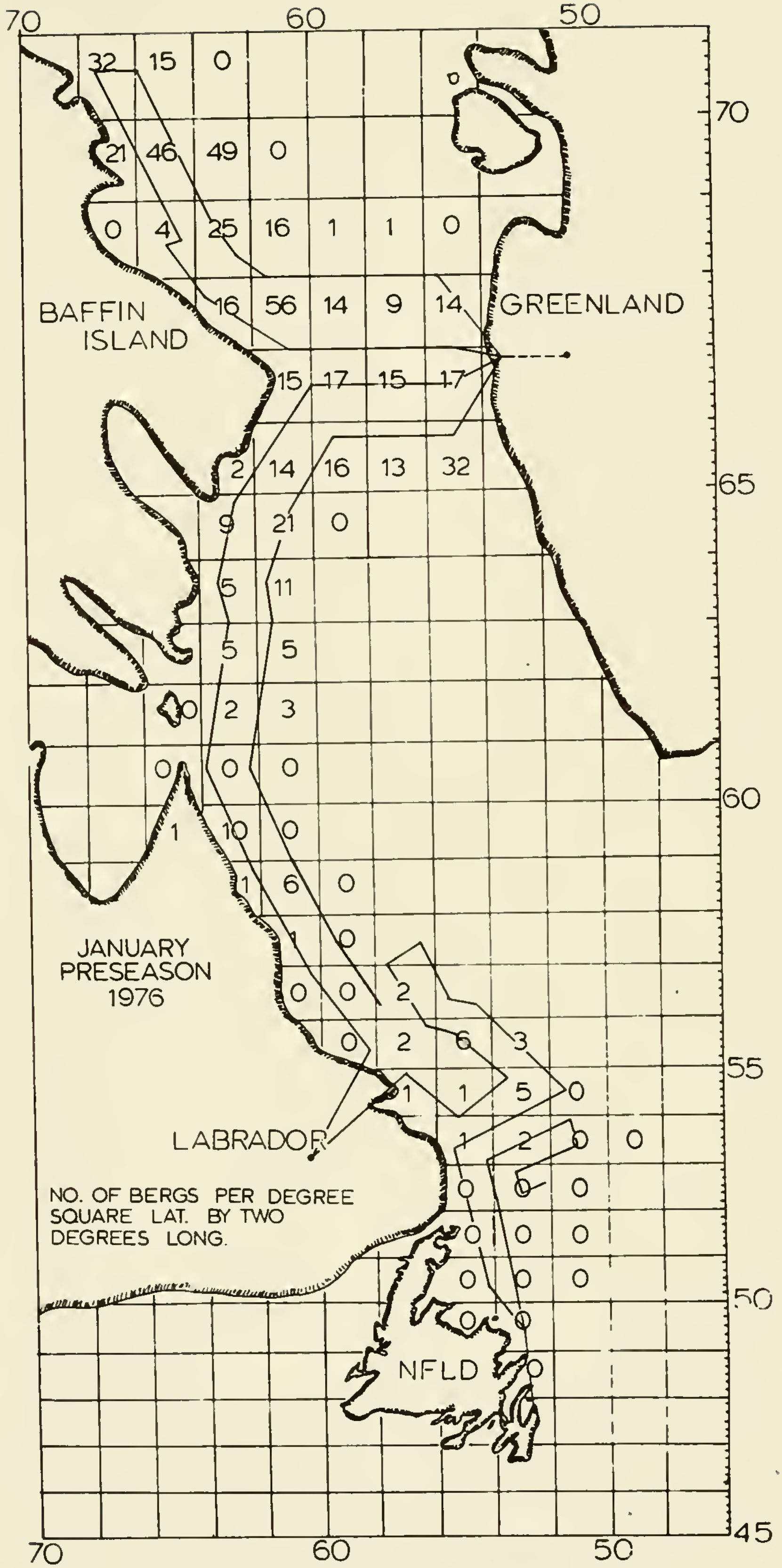

FIGURE 1.—Preseason Iceberg Survey, 1976

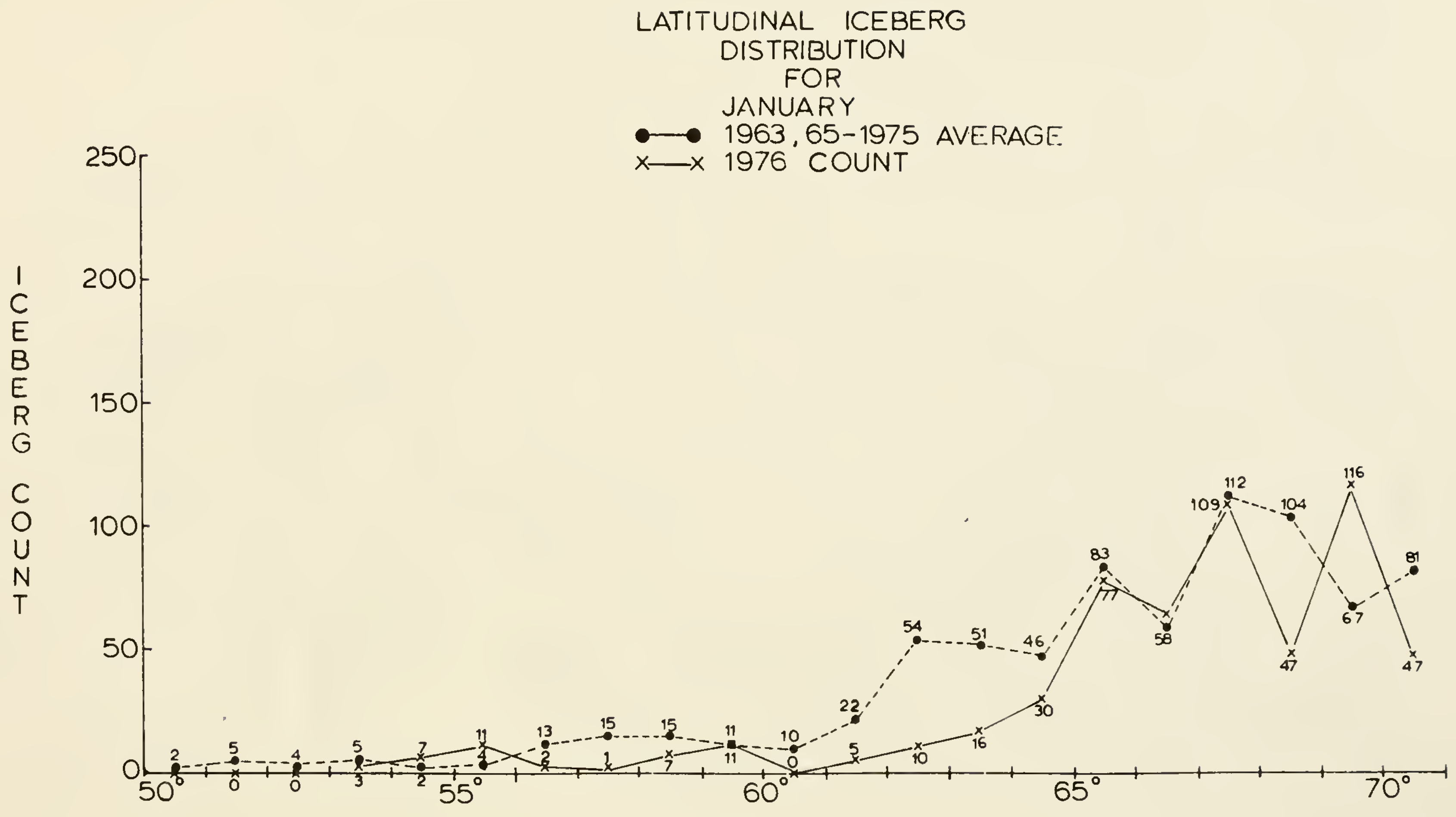

FIGURE 2.—Latitudinal Iceberg Distribution, January Preseason Survey

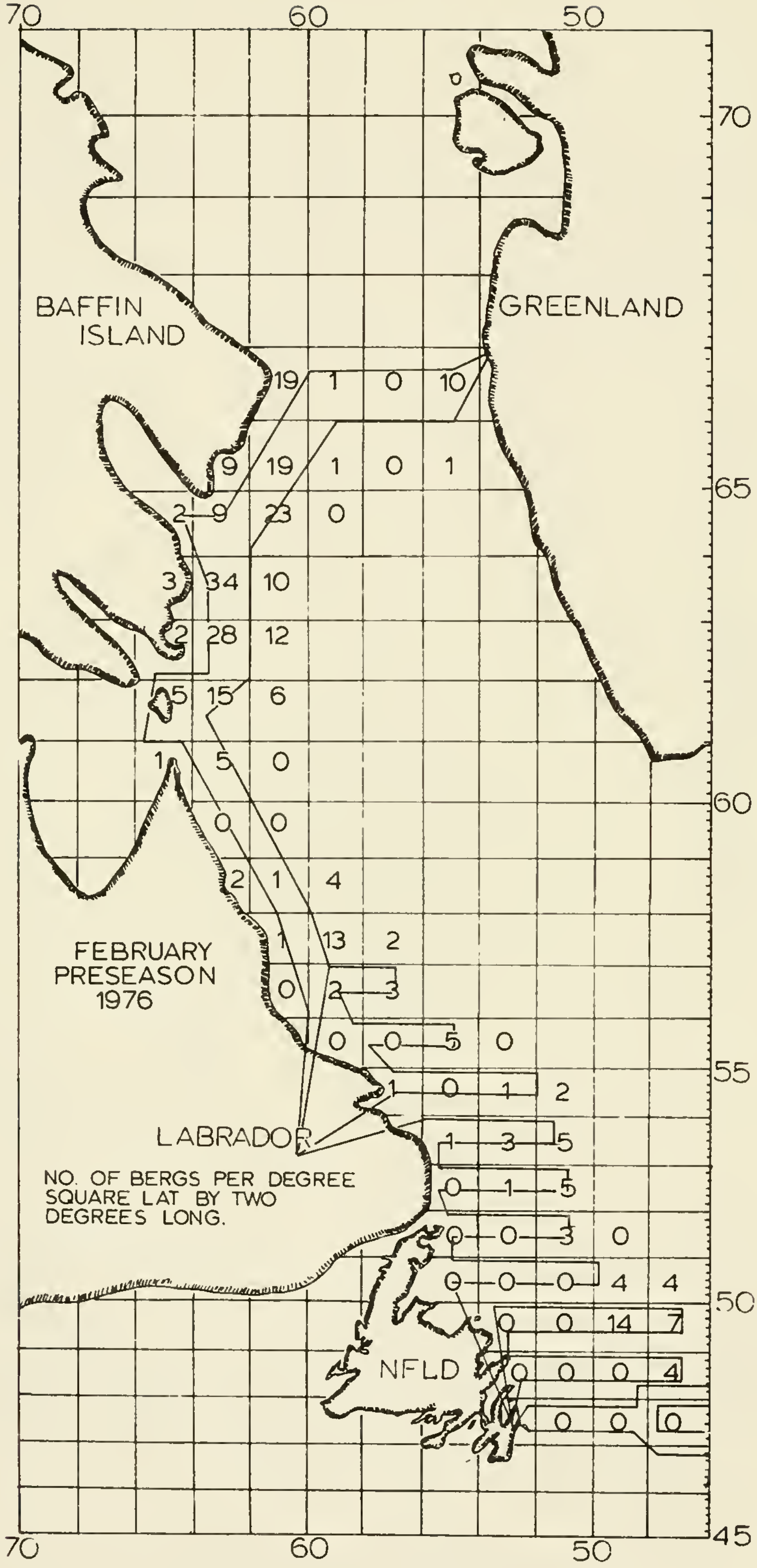

FIGURE 3.—Preseason Iceberg Survey, 1976

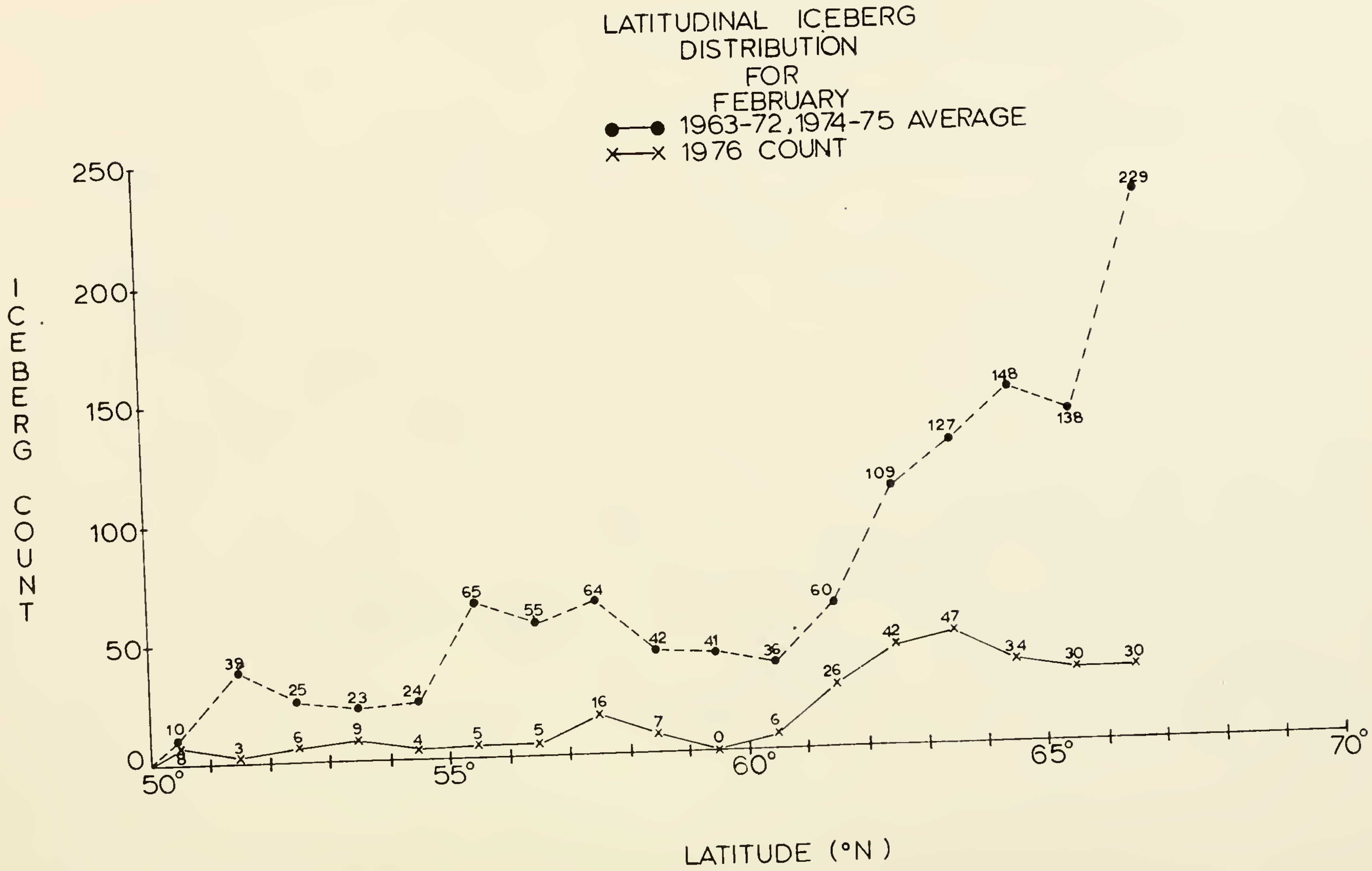

FIGURE 4.—Latitudinal Iceberg Distribution, February Preseason Survey

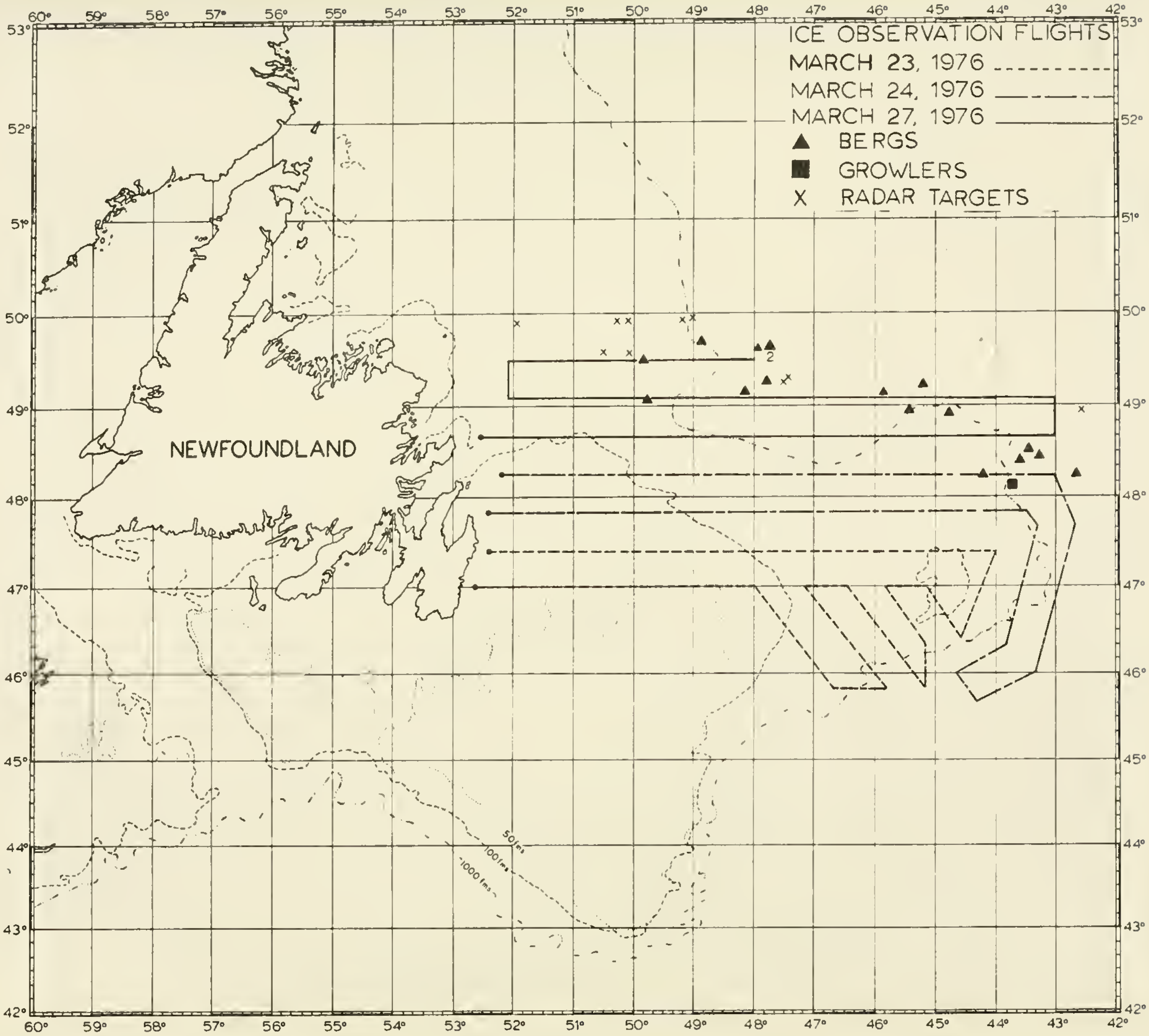

FIGURE 5.—Ice Observation Flights on 23, 24 and 27 March 1976

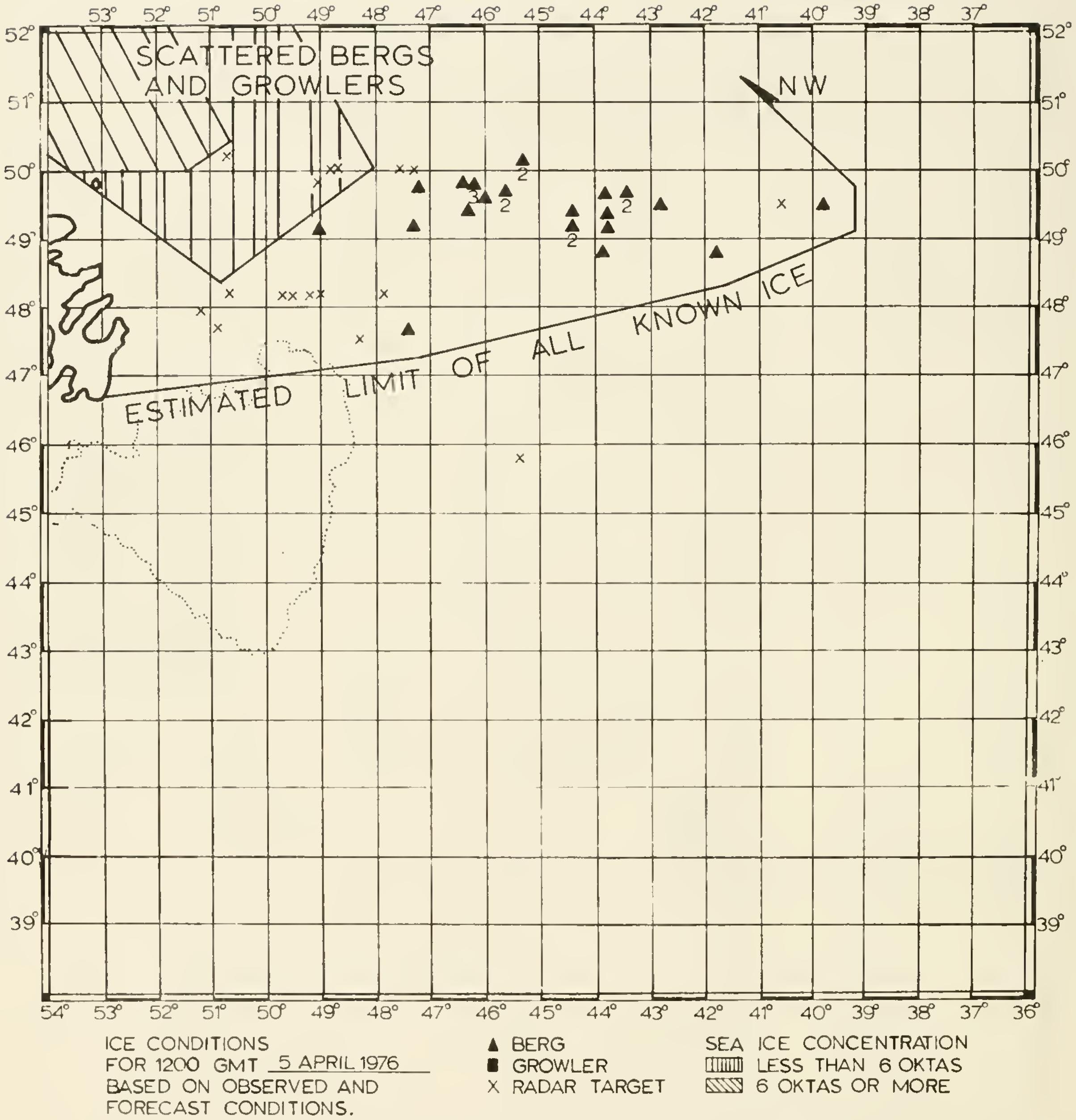

Figure 6.—Ice Conditions at 1200 GMT, 5 April 1976

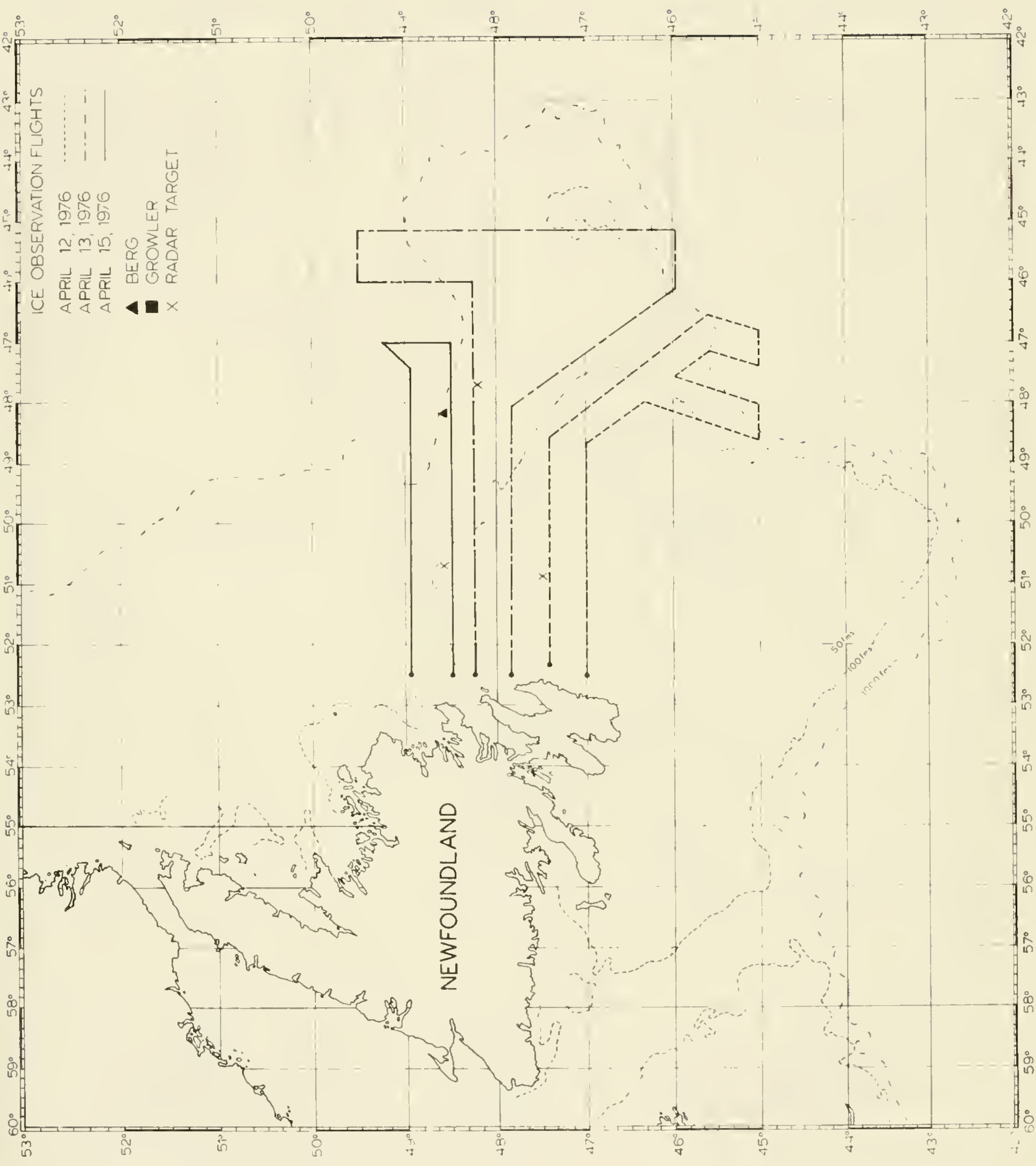

FIGURE 7.—Ice Observation Flights on 12, 13 and 15 April 1976

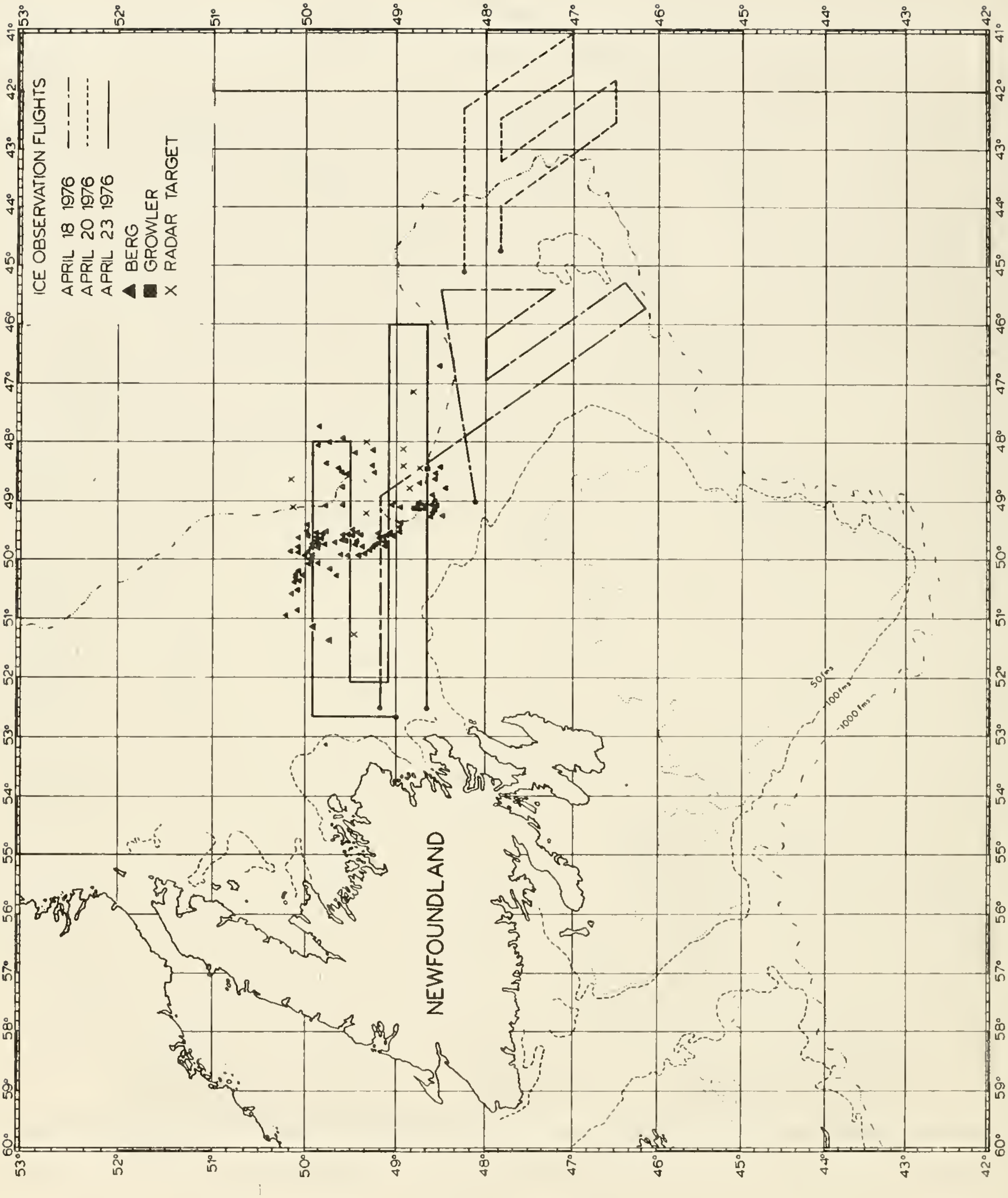

Figure 8.—Ice Observation Flights on 18, 20 and 23 April 1976

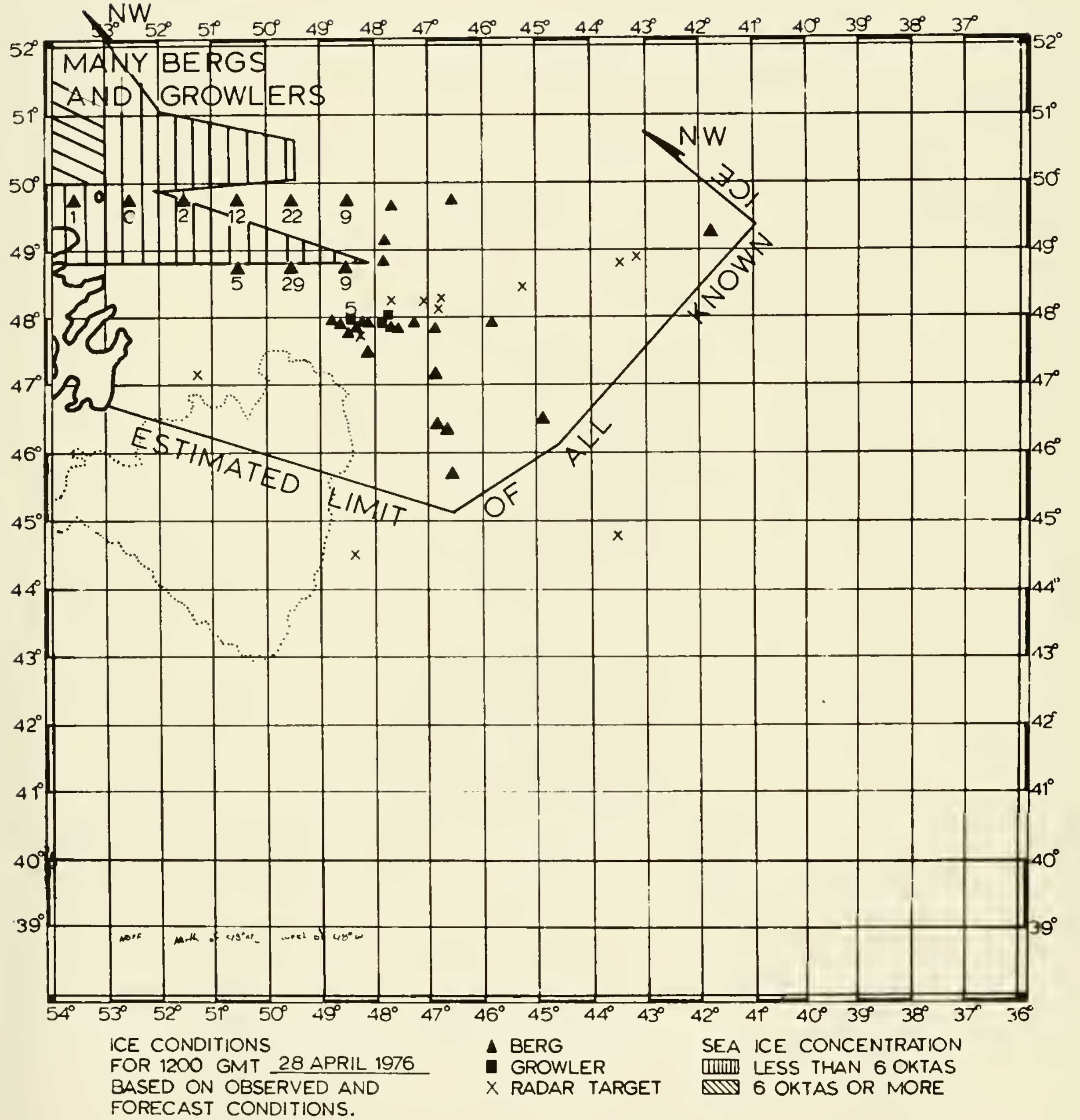

FIGURE 9.—Ice Conditions at 1200 GMT, 28 April 1976

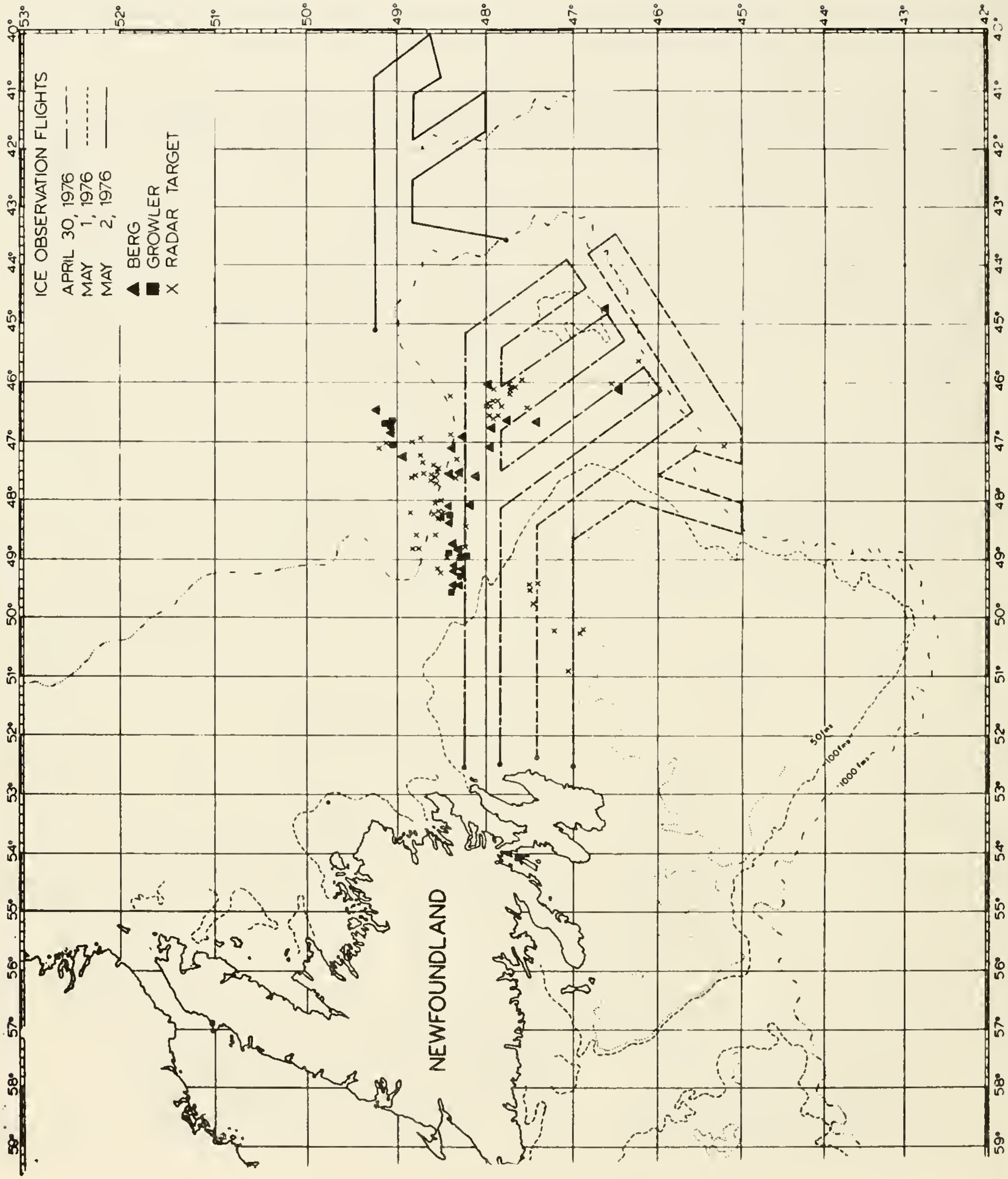

FIGURE 10.—Ice Observation Flights on 30 April and 1 and 2 May 1976

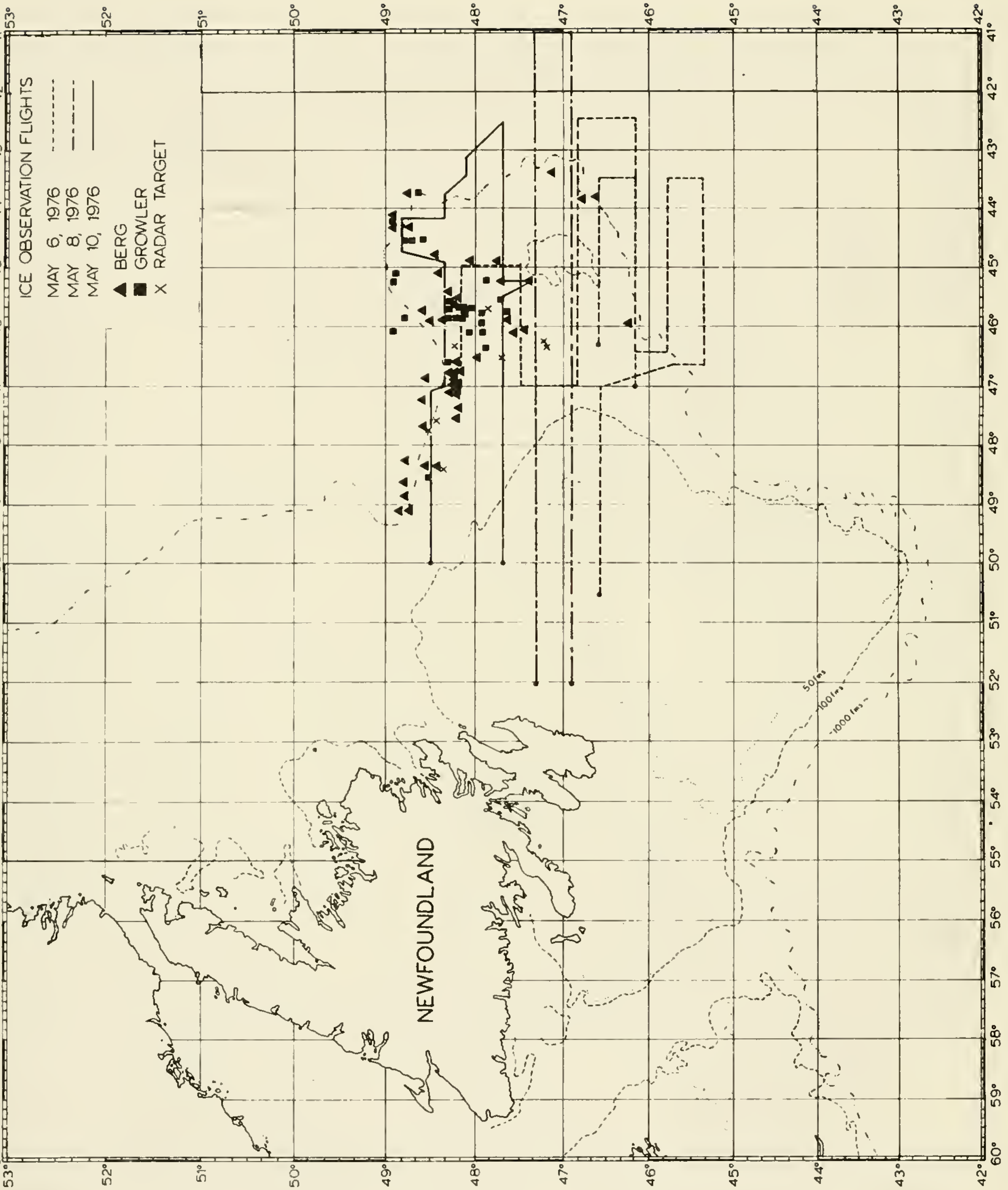

FIGURE 11.—Ice Observation Flights on 6, 8 and 10 May 1976

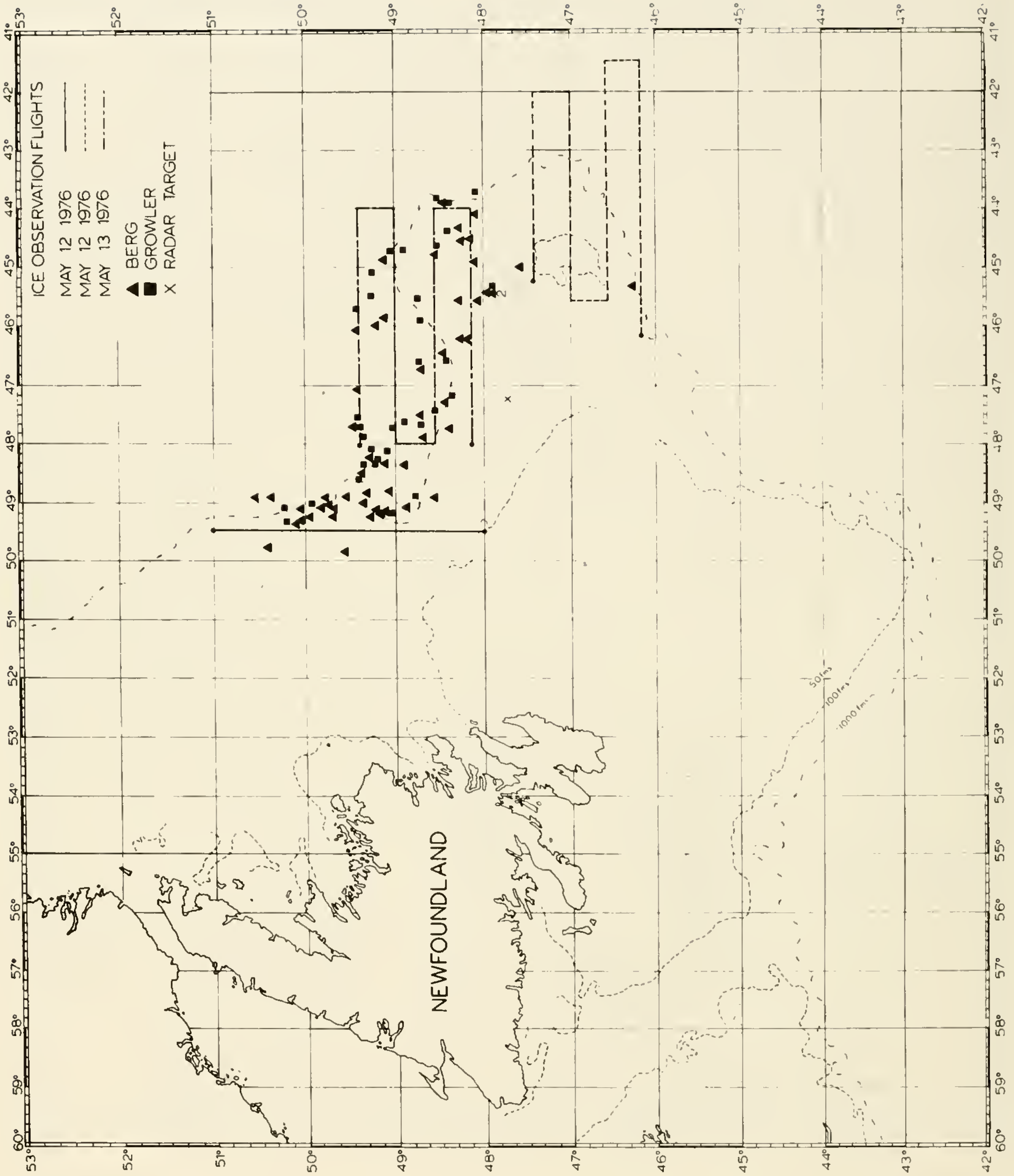

FIGURE 12.—Ice Observation Flights on 12 and 13 May 1976

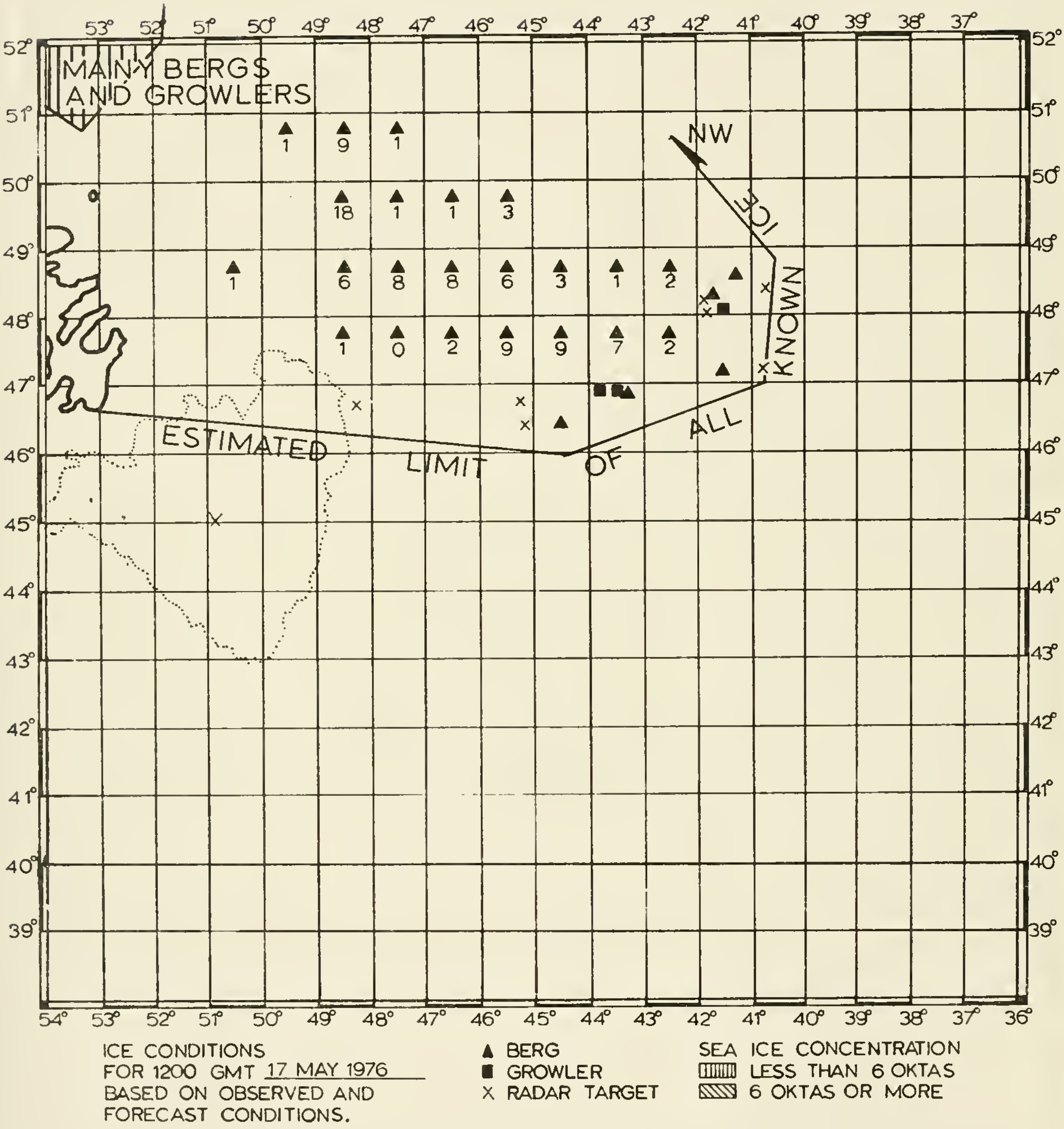

FIGURE 13.—Ice Conditions at 1200 GMT, 17 May 1976

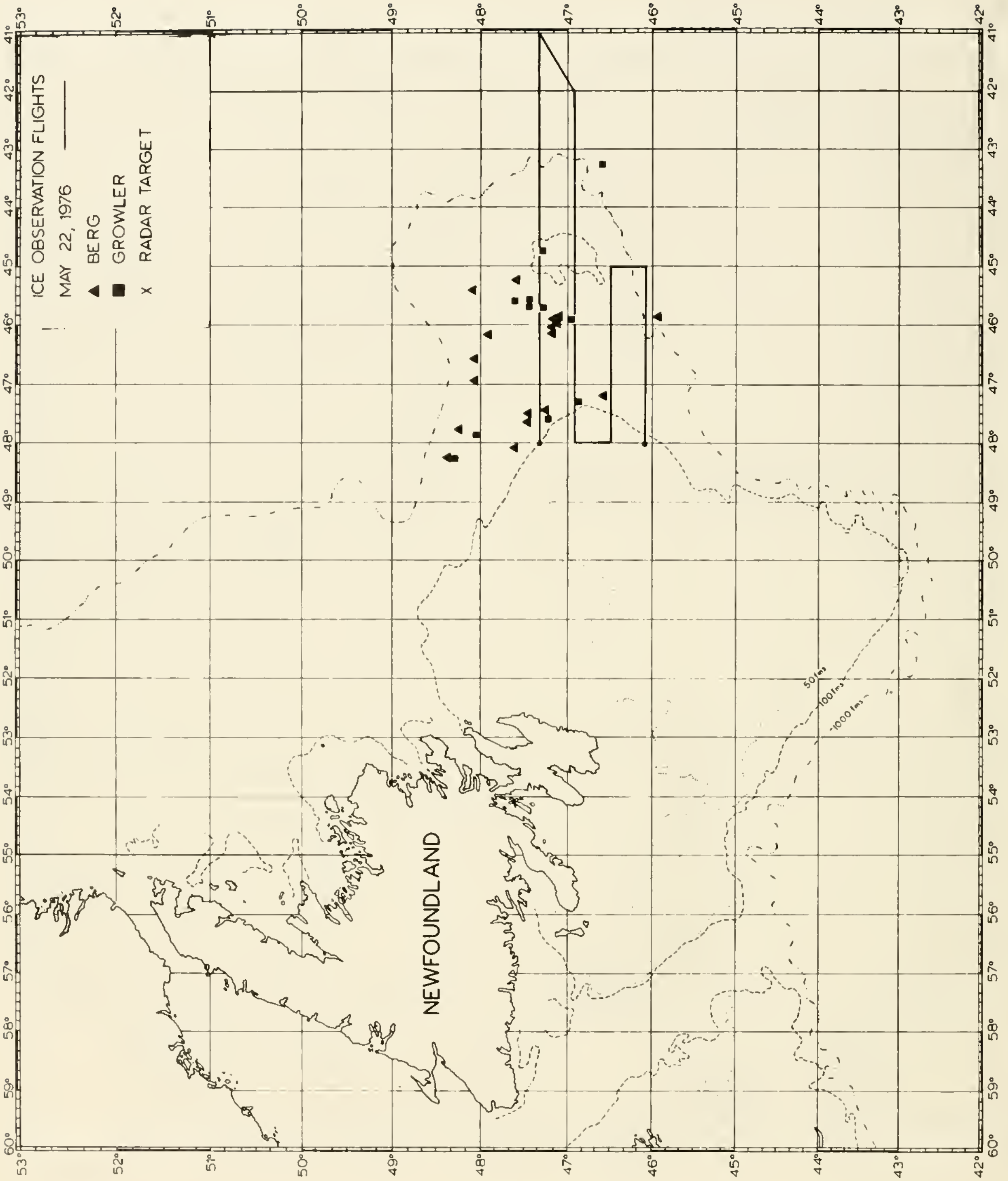

Figure 14.—Ice Observation Flight on 22 May 1976

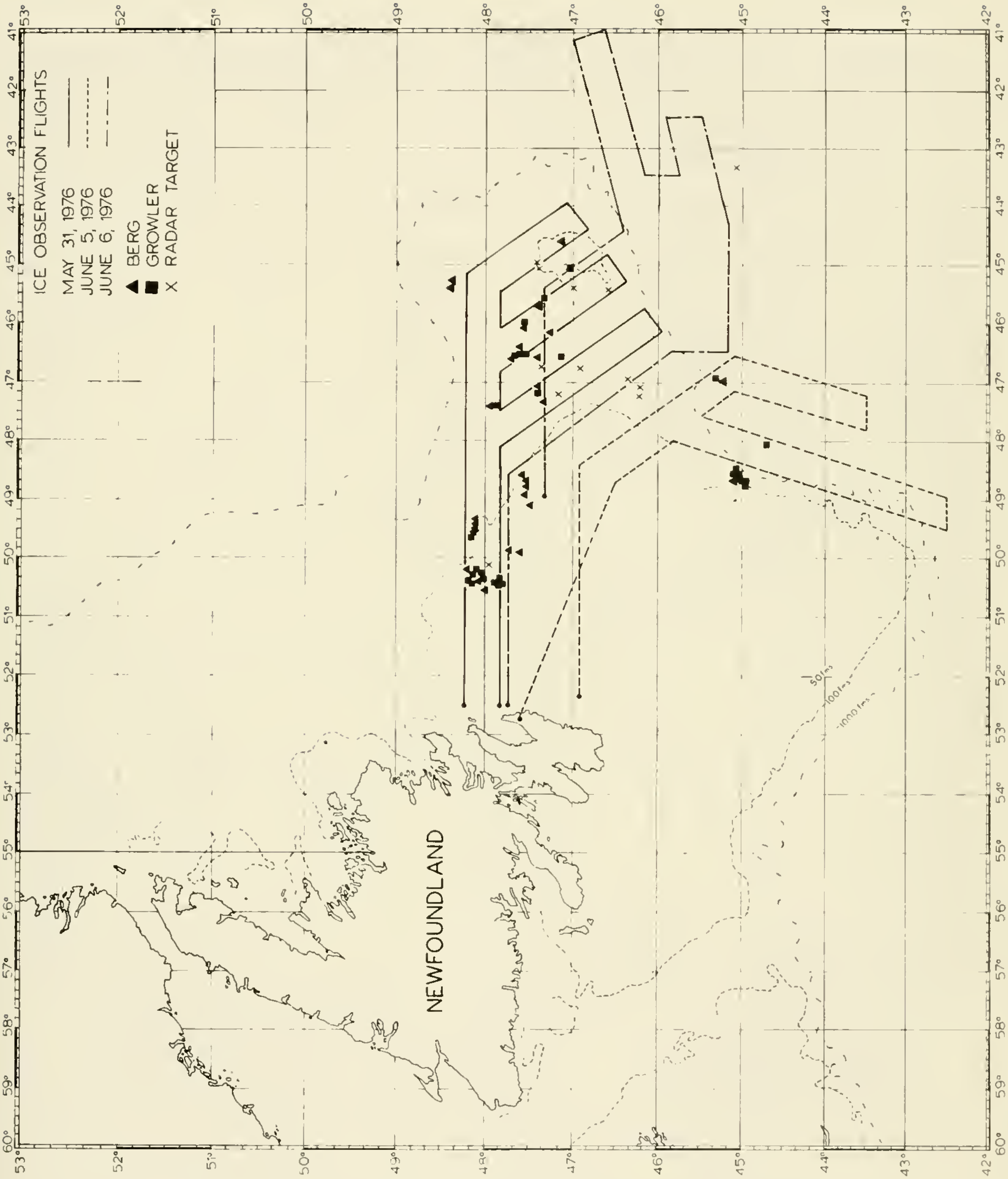

Figure 15—Ice Observation Flights on 31 May and 5 and 6 June 1976

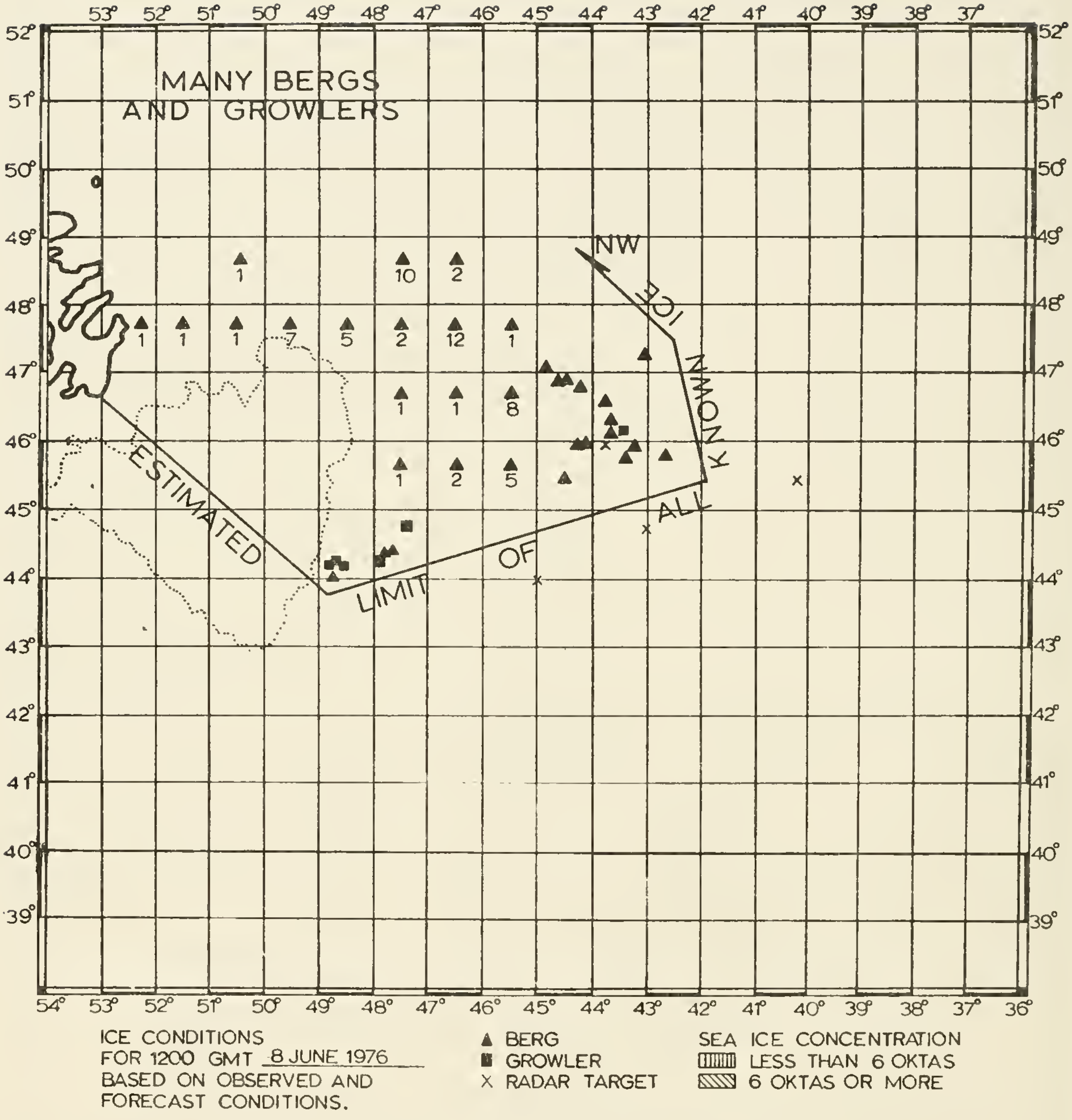

Figure 16.—Ice Conditions at 1200 GMT, 8 June 1976

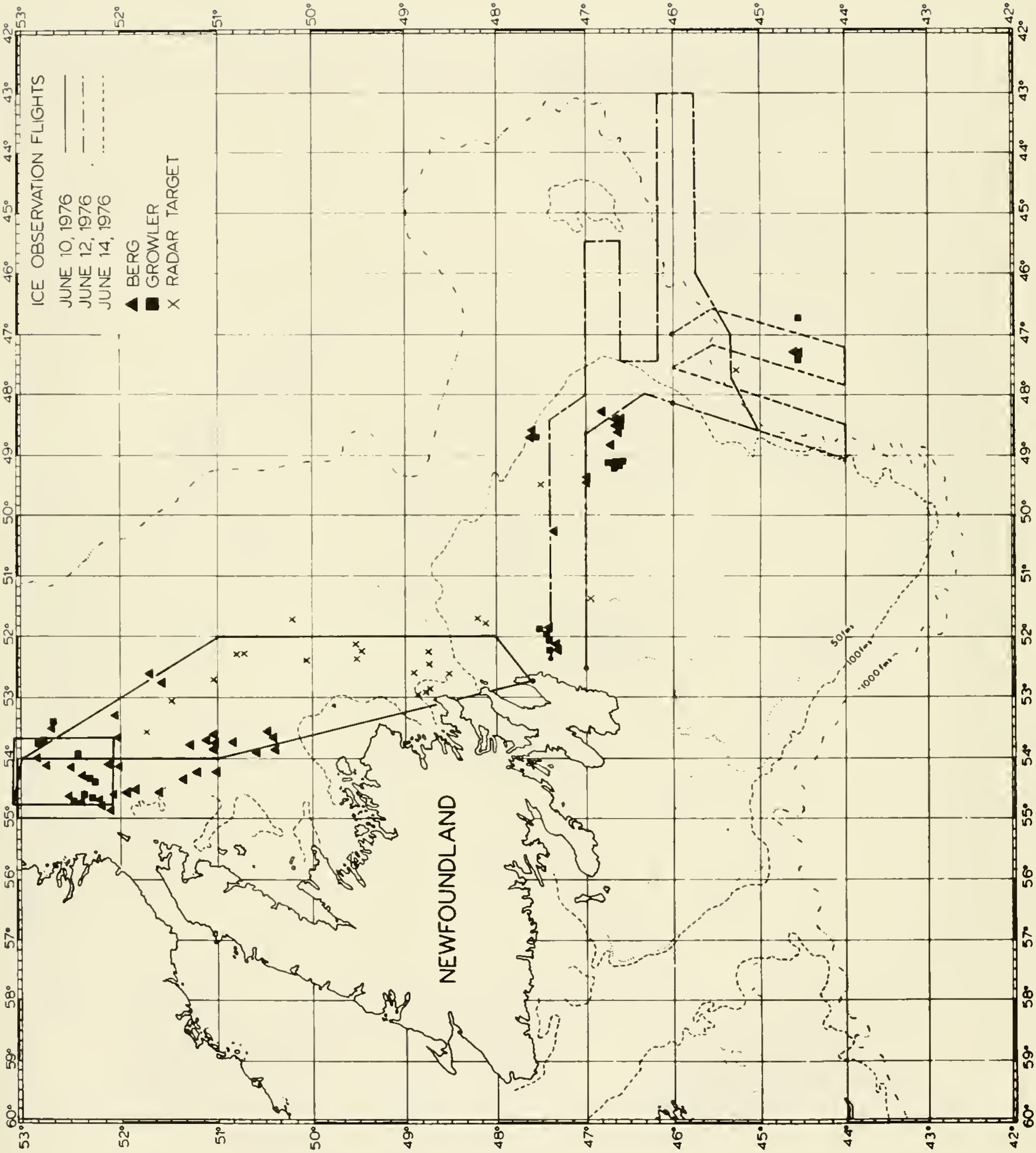

FIGURE 17.—Ice Observation Flights on 10, 12 and 14 June 1976

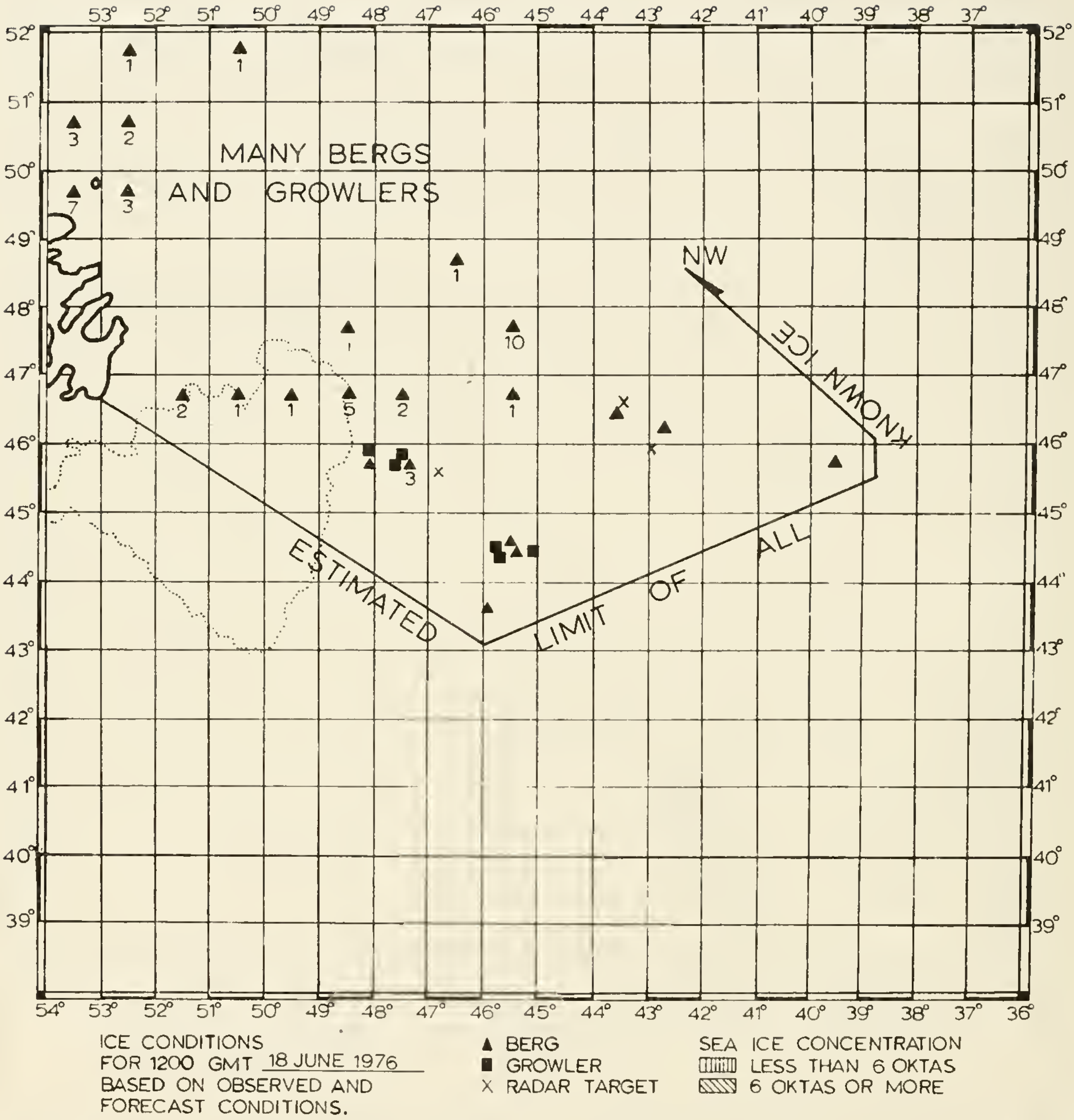

FIGURE 18.—Ice Conditions at 1200 GMT, 18 June 1976

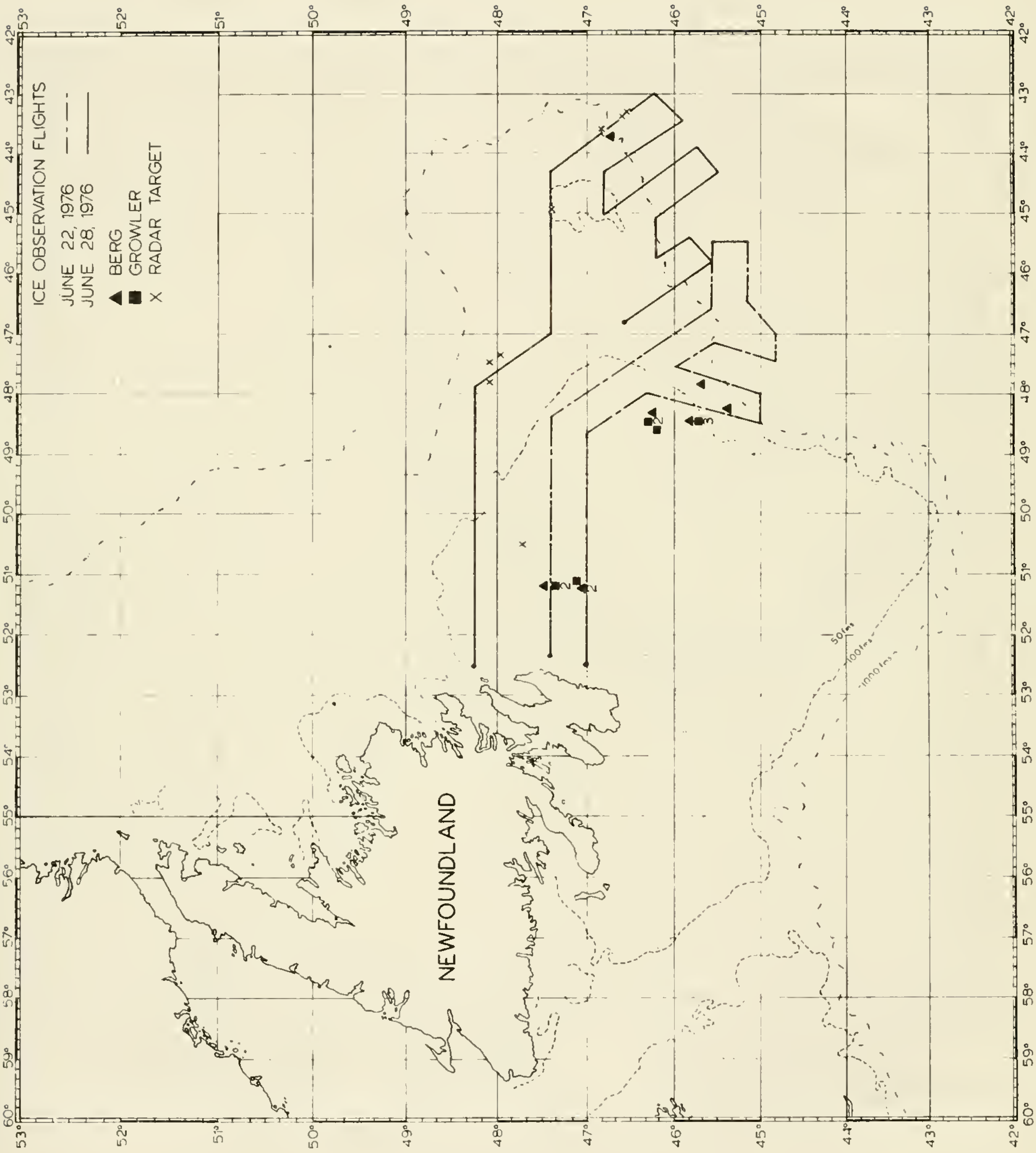

Figure 19.—Ice Observation Flights on 22 and 28 June 1976

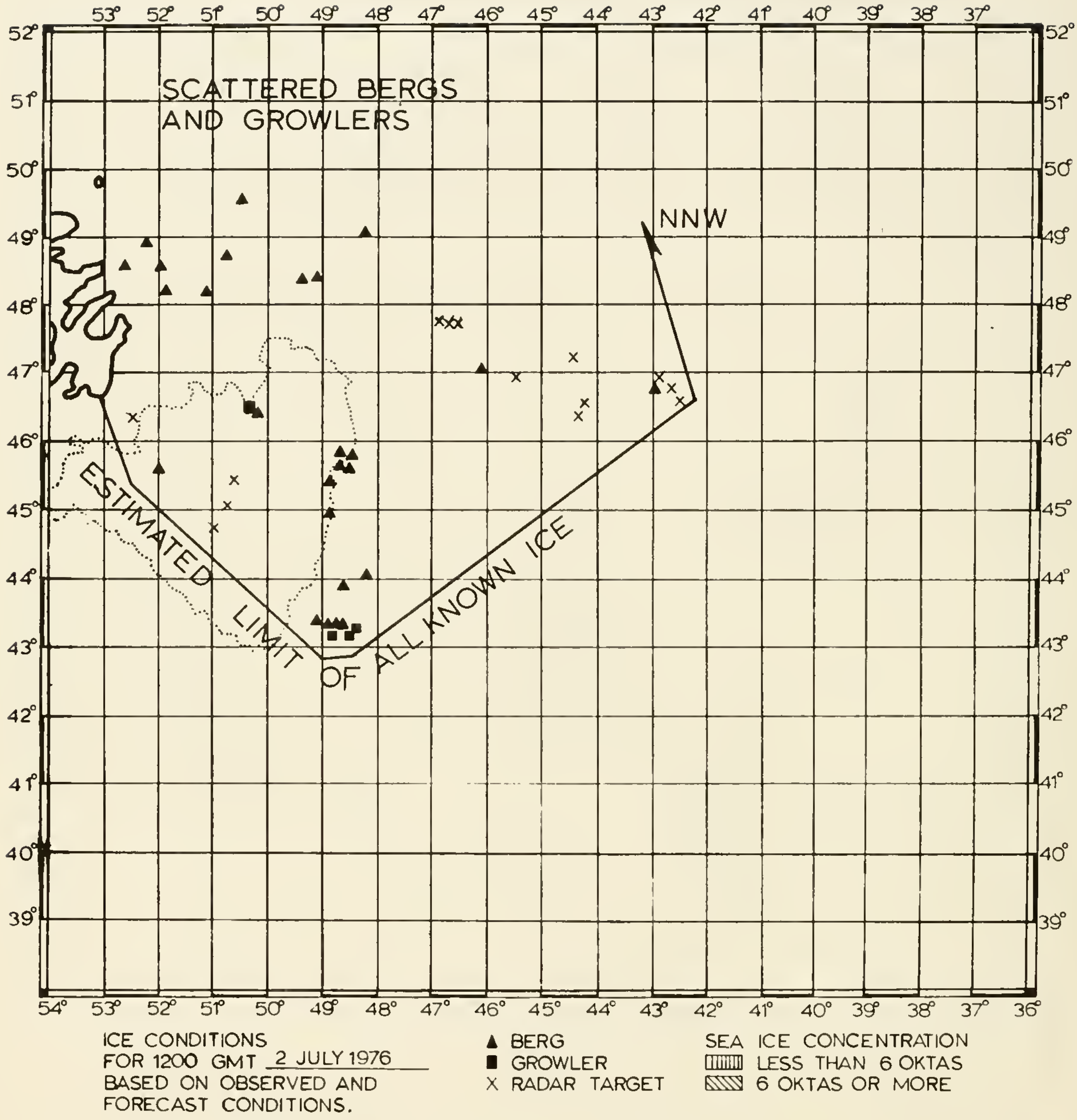

Figure 20.—Ice Conditions at 1200 GMT, 2 July 1976

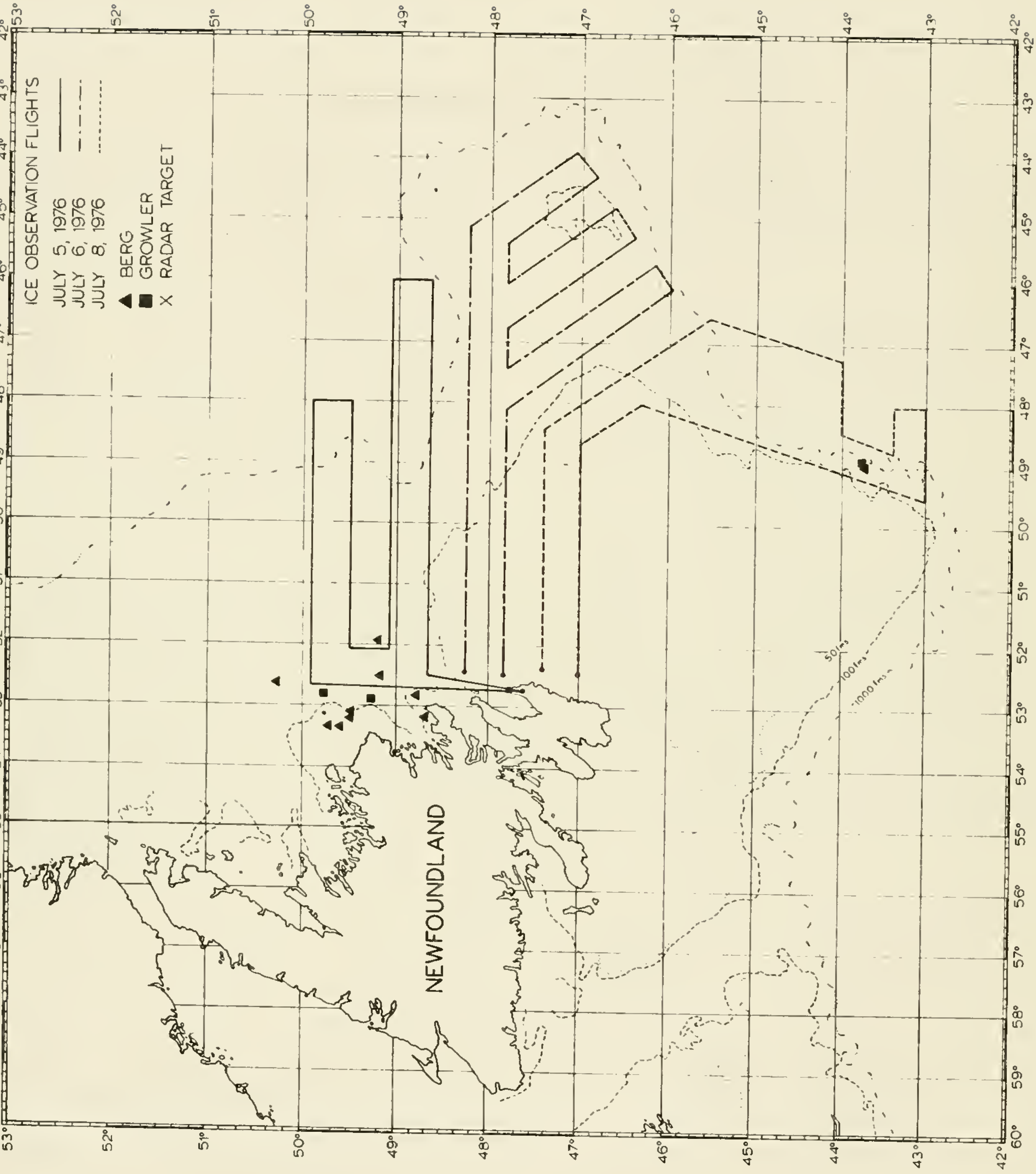

FIGURE 21.—Ice Observation Flights on 5, 6 and 8 July 1976

OCEANOGRAPHIC CONDITIONS, 1976

Two oceanographic cruises were conducted to the Grand Banks of Newfoundland from 25 March to 25 April and 18 May to 30 June during the 1976 Ice Patrol Season to provide real-time sea current data from dynamic topography surveys.

Additional objectives of these cruises aboard the USCGC EVERGREEN (WAGO 295) were research investigations of iceberg drift and deterioration. The research program included the use of satellite-tracked drogued drifting bouys (BTTs), *in situ* moored current meter arrays, and iceberg and drogue tracking experiments designed to aid in drift modelling.

In June 1976, a full dynamic topography survey encompassing section A4 to A1B (Figure 22) was performed in conjunction with an extensive survey conducted simultaneously in the waters to the east of the Grand Banks Ice Patrol standard sections by the USCGC SHERMAN (WHEC 720). The purpose of the USCGC SHERMAN cruise was to better understand the detailed dynamic characteristics of the North Atlantic Current after it leaves the Grand Banks and to determine the water properties of the associated water masses. The USCGC SHERMAN cruise data is the subject of a separate report.

The dynamic topography surveys were conducted by field parties from the Coast Guard Oceanographic Unit and the crew of the USCGC EVERGREEN using the Plessey Environmental System, Inc. Salinity/Temperature/Depth (S/T/D) or Conductivity/Temperature/Depth (C/T/D) Model 9040, Environmental Profiling Systems. The measurements were made to 1000 decibars (or to near bottom if shallower) and were recorded on magnetic tape (Kennedy Co., Model 1600R tape recorder) after formatting by a digital data logger (Sonicraft, Inc. DDL). For data processing details see Mountain (1978). The method of calculating dynamic height in water depth less than the reference level (1000 decibars for the Ice Patrol) is described in Kollmeyer (1967).

During the first cruise three current meter moorings were established in a triangular array centered at 42–47N, 47–47W. Deployment was accomplished by launching from the fantail of the CGC EVERGREEN with the anchor last technique while the ship steamed slowly forward. The moorings (Figure 23) each had two Vector Averaging Current Meters (VACM) and an acoustic release. Flotation was supplied by glass ball floats above each instrument and by two 31″ fiberglass covered syntactic foam floats at the top of each mooring. Mooring materials consisted of 3/16″ wire from the top floats to the release and 5/8″ nylon line from the release to the anchor.

Attempts to recover the current meter arrays during the second cruise were unsuccessful. The acoustic releases were interrogated and commanded to release. All releases responded as if disengagement had occurred. However, no signal from the submersible radio transmitters and no sighting was made of the current meter mooring on the surface even after an extensive search was made. The acoustic releases were heard pinging continuously in place for the life of the battery (about 5 hours). Dragging attempts in both 1976 and 1977 also failed to recover the moorings. The cause of failure of the moorings to surface remains unknown.

The results of the iceberg tracking study for drift and deterioration appears in a separate section in this bulletin.

The contoured field of dynamic topography on the first cruise (Figure 24 and 25) reveals a pattern of flow similar to the average conditions (Figure 26). The Labrador Current flows southward through Flemish Pass following the eastern edge of the Grand Banks. Surveys from the second cruise (Figure 27) provide a full coverage of the area bounded by the standard Ice Patrol sections. The dynamic height field at this time exhibits good agreement with the normal topography in the northern sections of the survey,

but the location and density of the dynamic height isopleths indicates that the North Atlantic Current as it passes across section A4 to 40–60 nautical miles north of its average position.

The full dynamic topography survey provided an opportunity to study the variation of the transport and minimum temperature in the Labrador Current as it flowed southward. Both the total southerly transport and the Cold Core transport (less than 2°C and 34.3°/₀₀) have been calculated (Figure 28). Only about half of the Labrador Current at section A1B turned southward to follow the eastern slope of the Grand Banks. This southward flow remained relatively constant between sections A2 and A3B at about 2.5 Sv. The transport values computed for these sections are comparable in volume to the Labrador Current transports measured in recent years, but was below the long-term average of about 3.5 Sv (Bullard, *et al.*, 1961). At sections A3B MOD and A3C the transport inexplicably increased. When the flow had reached section A4, the volume transport had decreased almost to zero because of the unusually northerly location of the North Atlantic Current. This had a damming effect on the Labrador Current preventing its usual turn to the west around the Tail of the Bank. The minimum temperatures measured in the Labrador Current were nearly the same with the northernmost section showing the coldest water and the southernmost section having the warmest water as expected. Average minimum temperature was about 1.2°C (Bullard, *et al.*, 1961).

Although the effect on the Labrador Current of the impingement by the North Atlantic Current on the Tail of the Bank can easily be seen in the contoured dynamic height field (Figure 27), a temperature-salinity (T–S) graphical analysis was made to confirm and explore the presence of the blockade (Figures 29a and 29b). From the T–S curves it is evident that very little volume with Labrador water properties reaches section A4. The small volume of Labrador water present on section A4 (all of which is below approximately 25 meters in the three northernmost stations) represents a volume transport only 4% of that found on the next section, A3C. Furthermore, whereas the minimum temperatures of the upstream section, A3C, are −0.41°C, −1.2°, and −1.4°C for stations 12112 to 12114, the minimum temperatures for the comparable stations 12089–12091 on section A4 are +1.2°C, 0.0°C, and −1.0°C. The salinity is quite similar for all six stations at about 33.0°/₀₀ to 33.2°/₀₀. On A3C water with Labrador properties is seen out to station 12106.

Since the continental slope rises sharply to the west, little of the volume transport from the blocked Labrador Current can be transported onto the shelf. Consequently, most of the volume flow must be turned eastward to flow along with the North Atlantic Current. This northward migration of the North Atlantic Current on section A4 is very similar to the conditions observed during the 1973 Ice Patrol Season (Hayes and Robe, 1978).

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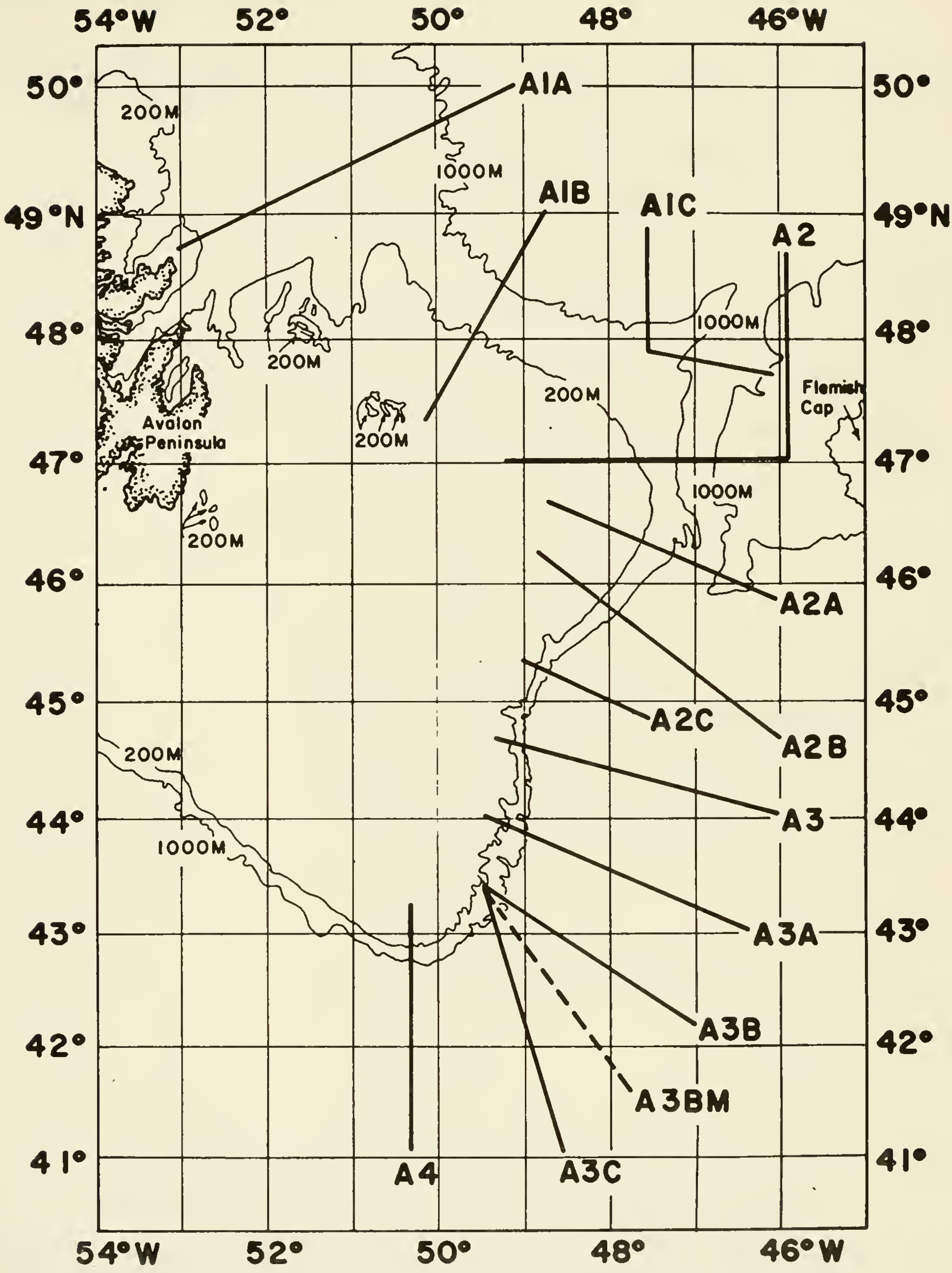


FIGURE 22.—Standard International Ice Patrol Sections

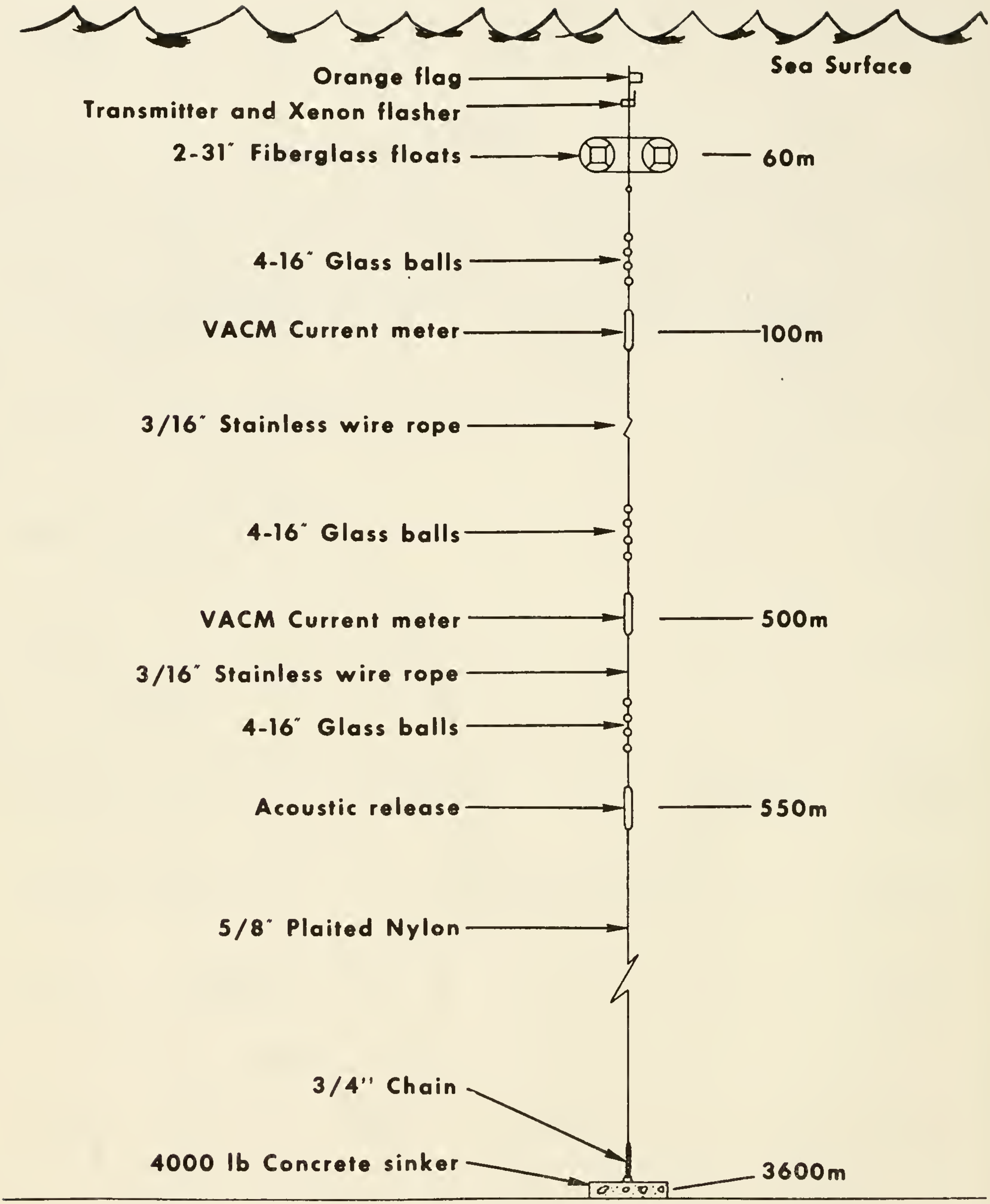


FIGURE 23.—Schematic diagram of the current meter moorings displayed in 1976

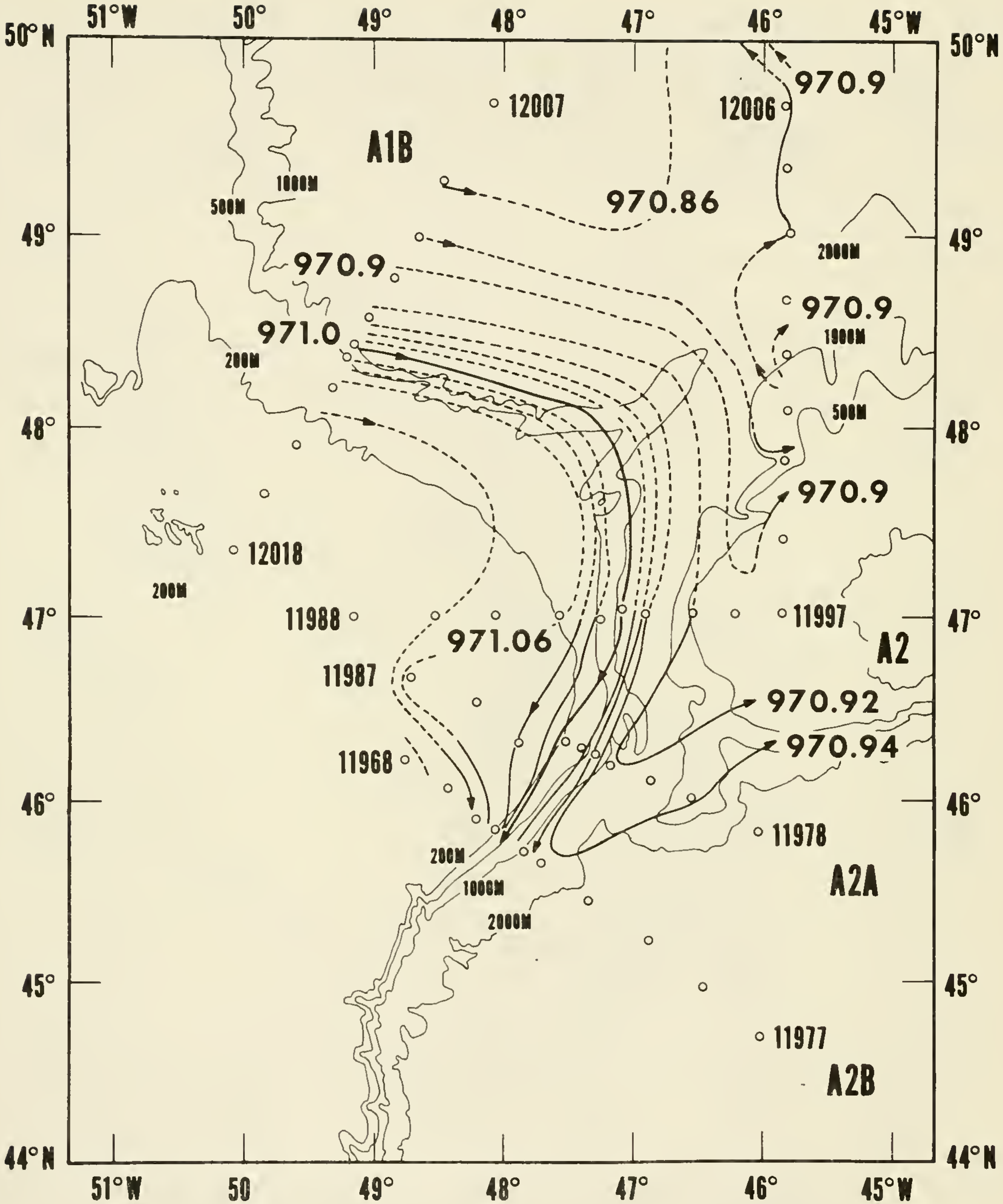


FIGURE 24.—Sea surface dynamic topography (dynamic meters) relative to 1,000 decibar level, CGC EVERGREEN, 1-6 April 1976. Contour level is 2 dynamic centimeters. Station numbers indicate turning points.

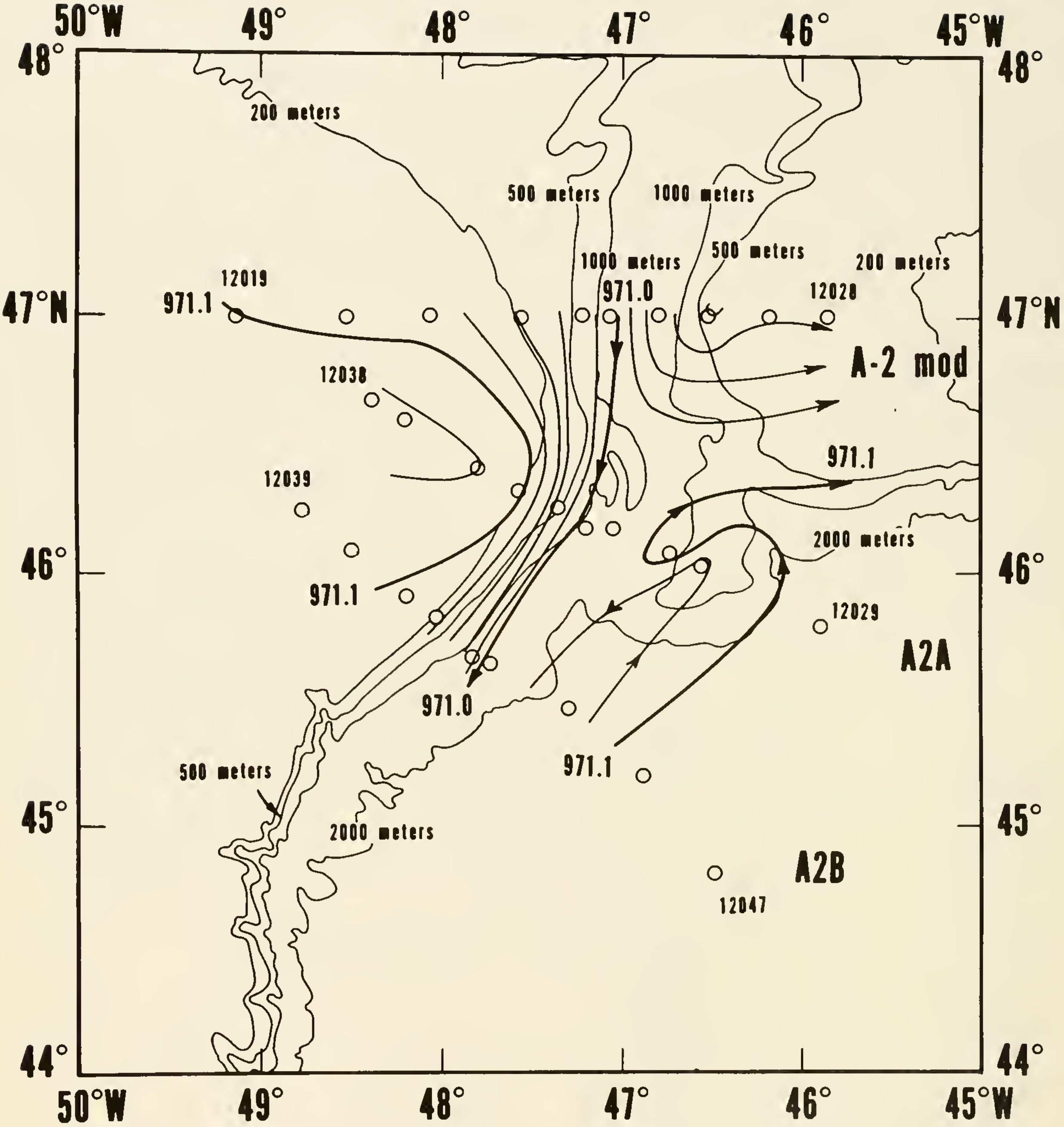


FIGURE 25.—Sea surface dynamic topography (dynamic meters) relative to the 1,000 decibar level. CGC EVERGREEN, 17–19 April 1976. Contour level is 2 dynamic centimeters

MONTHLY NORMAL DYNAMIC TOPOGRAPHY FOR APRIL

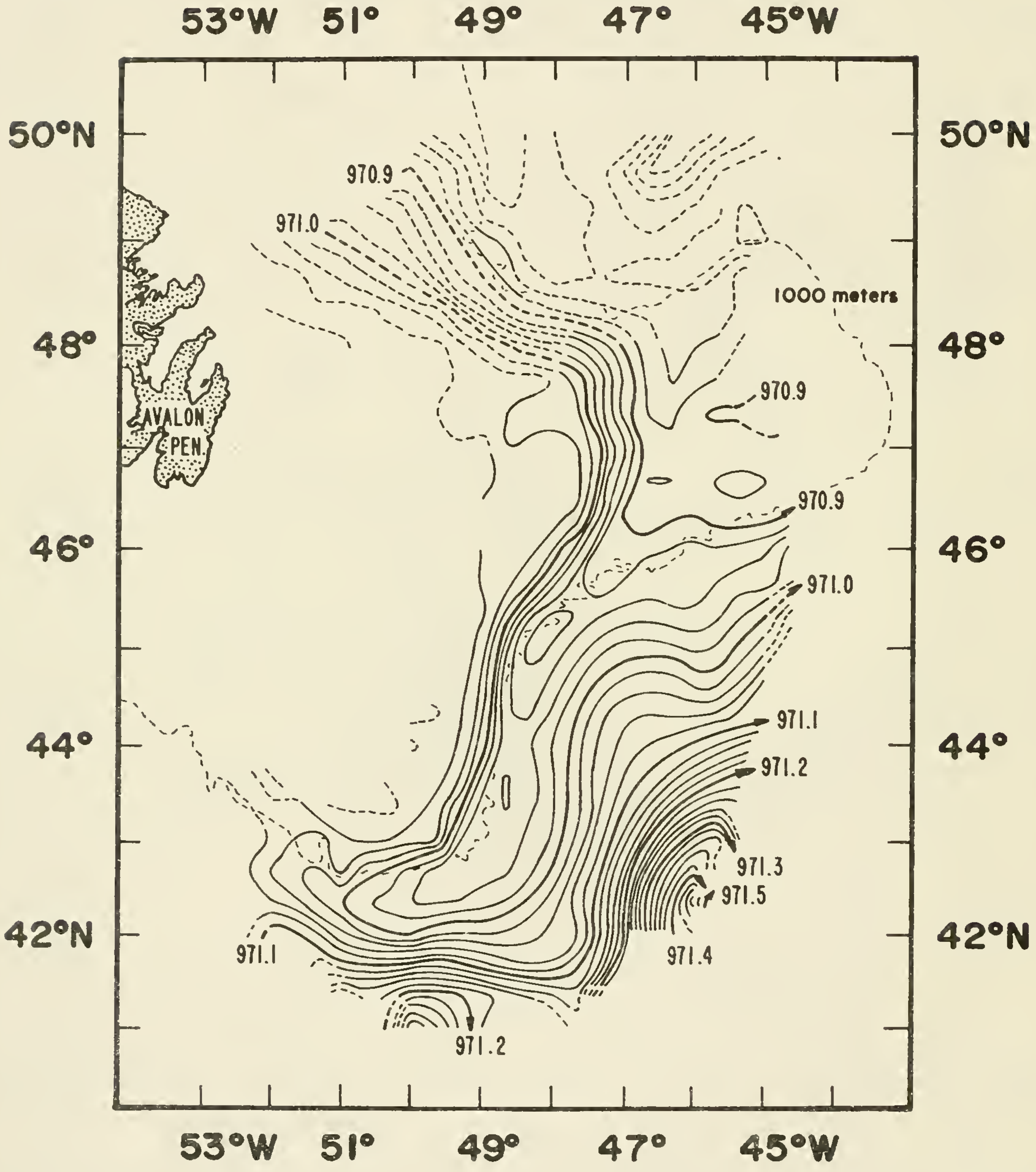


FIGURE 26.—April monthly normal dynamic topography (dynamic meters) of the sea surface relative to the 1,000 decibar surface. Contour interval is 2 dynamic centimeters

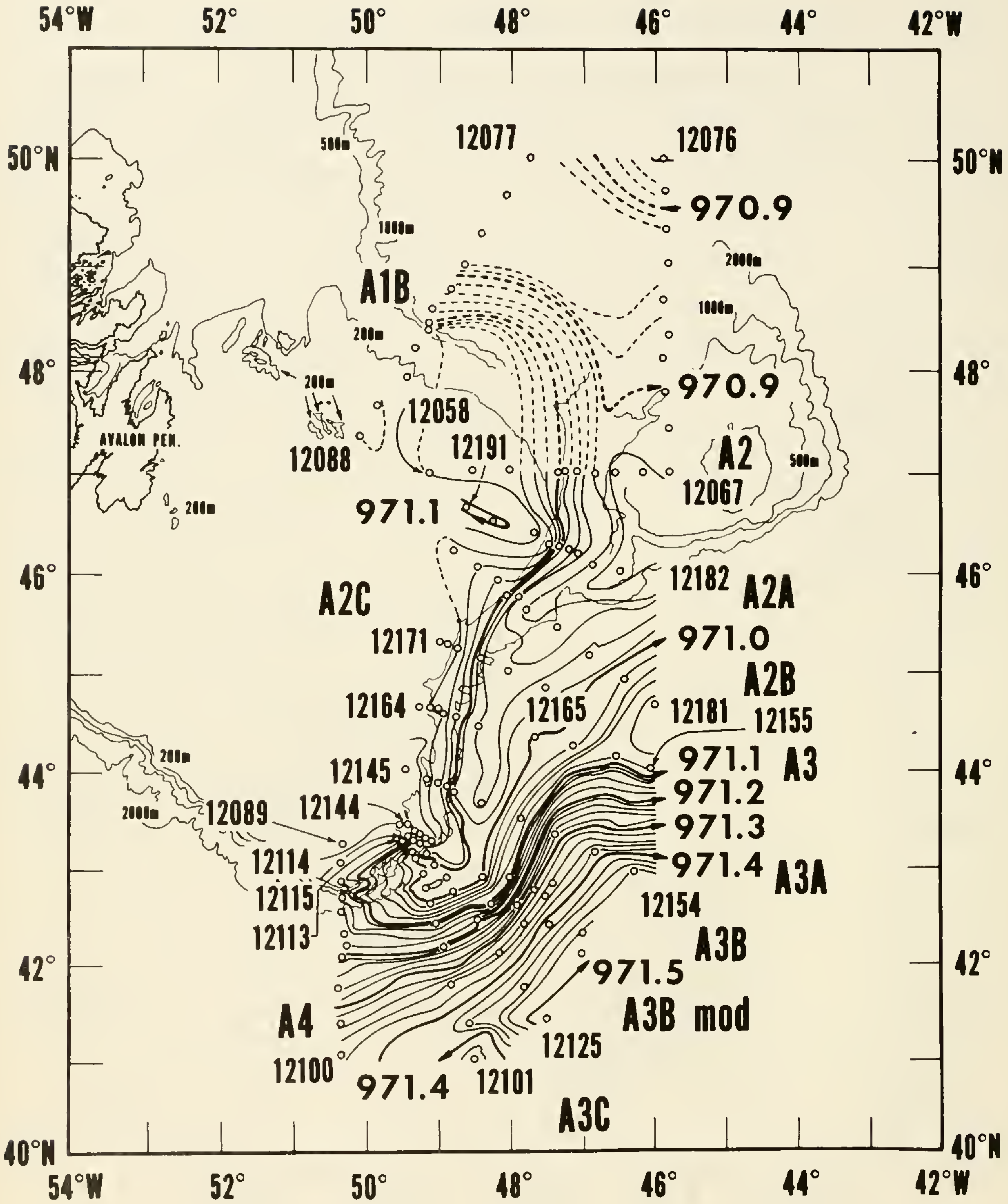
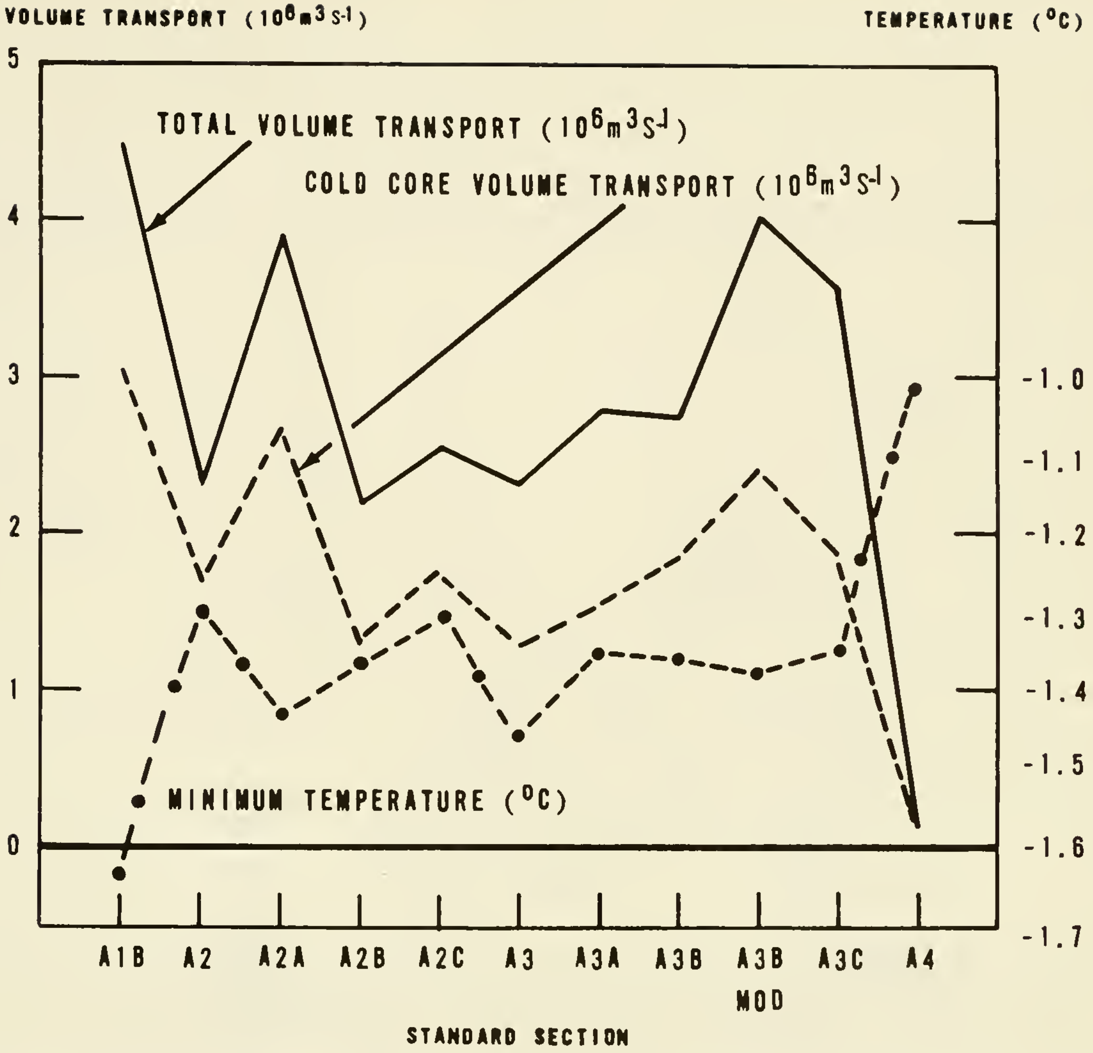


FIGURE 27.—Sea surface dynamic topography (dynamic meters) relative to the 1,000 decibar level, CGC EVERGREEN, 8–20 June 1976. Contour interval is 2 dynamic centimeters



	TOTAL VOLUME TRANSPORT	COLD CORE TRANSPORT	MINIMUM TEMPERATURE
A1B	4.47	3.04	-1.63
A2	2.30	1.70	-1.30
A2A	3.90	2.65	-1.43
A2B	2.19	1.28	-1.36
A2C	2.53	1.74	-1.30
A3	2.30	1.27	-1.46
A3A	2.79	1.53	-1.35
A3C	2.75	1.87	-1.36
A3B MOD	4.02	2.41	-1.38
A3C	3.56	1.87	-1.35
A4	0.13	0.08	-1.04

FIGURE 28.—Comparisons of total volume transport, Cold Core volume transport, and minimum temperatures during the full dynamic topographic survey, 8–20 June 1976

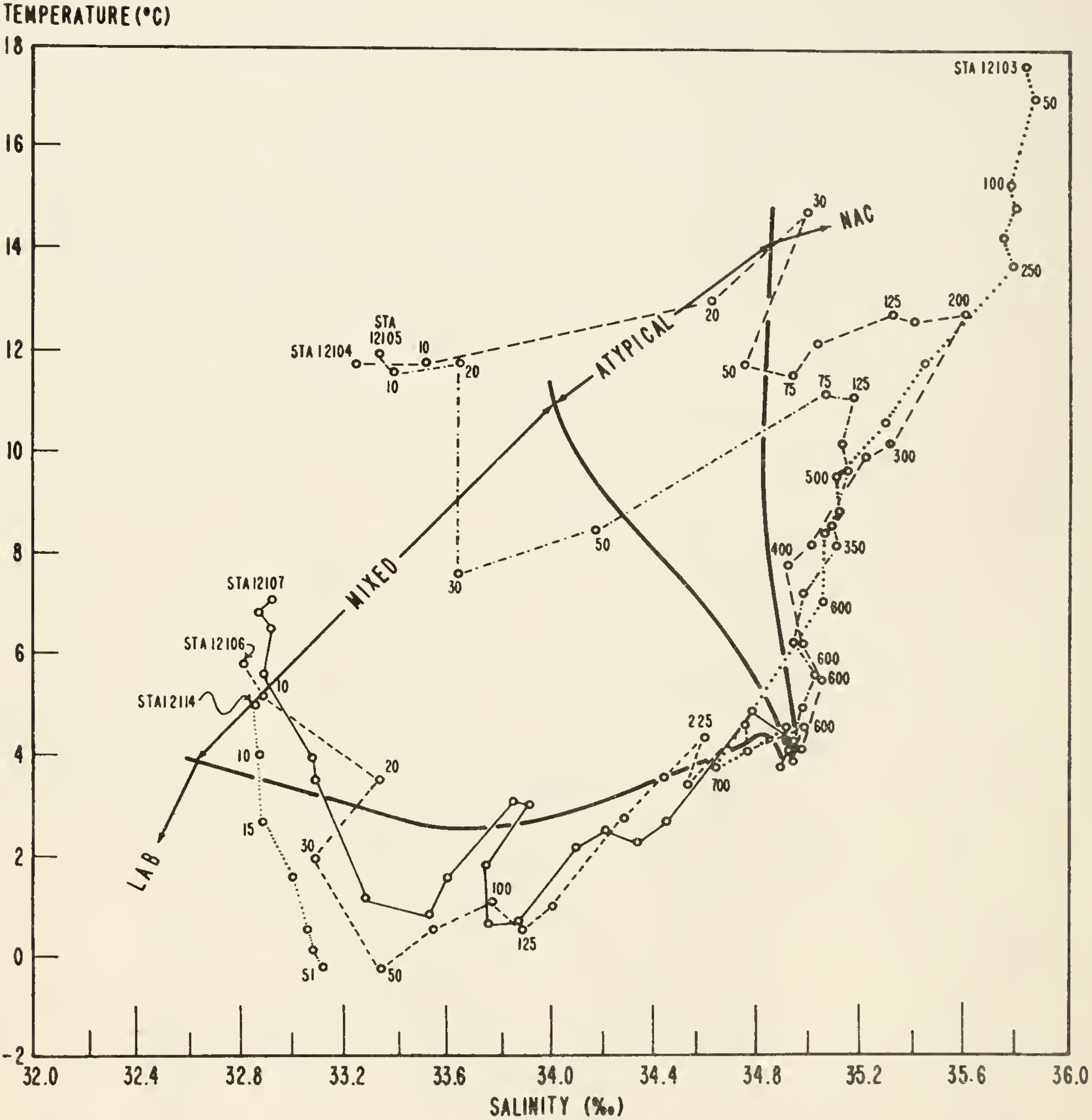


FIGURE 29a.—Temperature—Salinity diagram of selected stations for section A3C, 9–11 June 1976

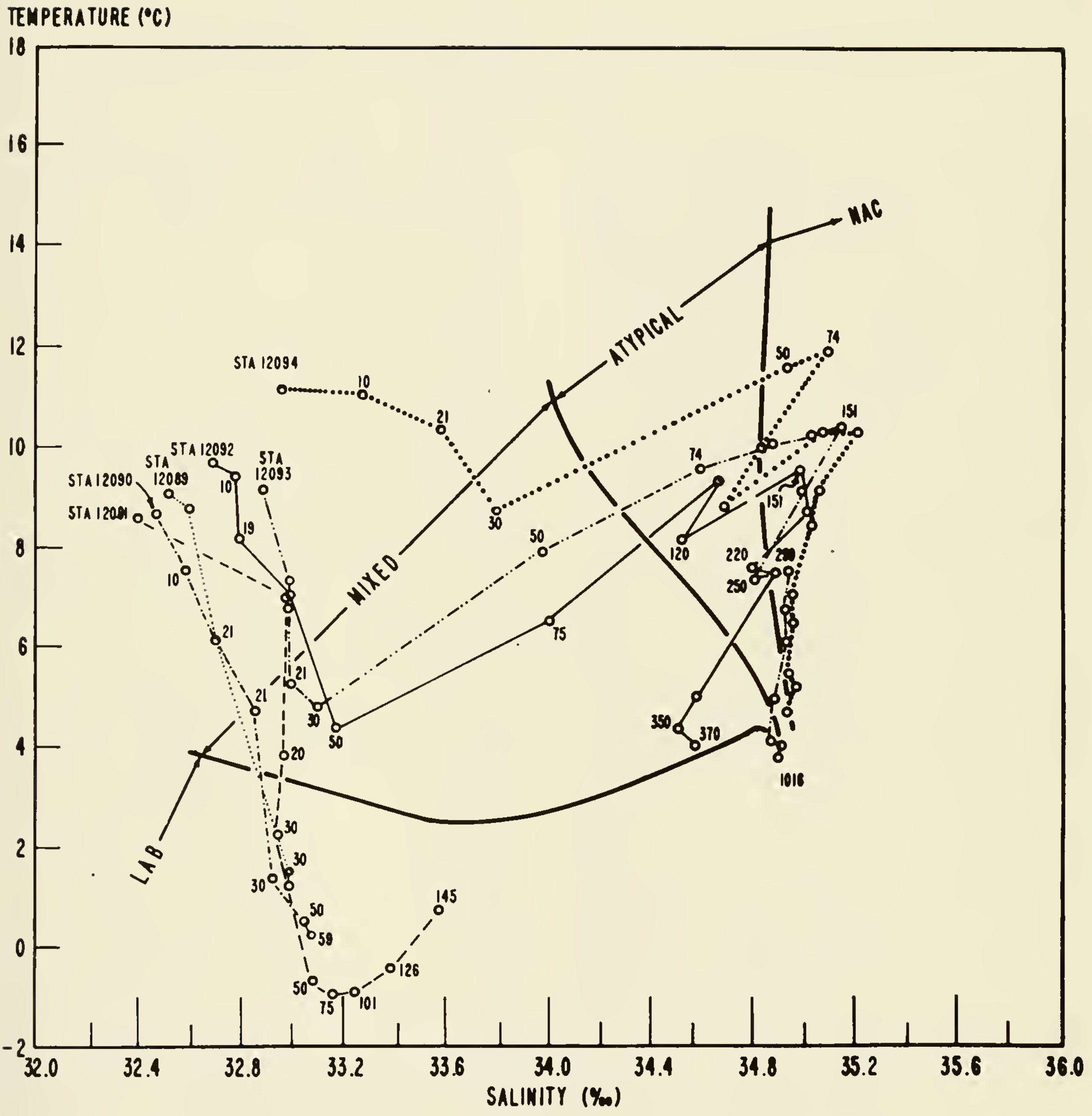


FIGURE 29b.—Temperature—Salinity diagram of selected stations for section A4, 6–9 June 1976

DISCUSSION OF ICEBERG AND ENVIRONMENTAL CONDITIONS
1976 SEASON

The 1976 season was the second light season in a row, with only an estimated 151 icebergs crossing 48°N. This is less than half the 1946–1975 average of 315 bergs. In attempting to explain why this was a relatively mild season, several environmental factors must be considered. These include the number of bergs available to drift across 48°N, the strength, duration and direction of the winds that affect southerly iceberg drift, the sea ice cover that protected the bergs from melt, the strength and position of the Labrador current (discussed in the Oceanographic Conditions Section), and finally the various parameters which determine the deterioration rate of icebergs.

During the January Preseason flights, a total of 563 bergs were sighted between 53°N and 71°N as shown in Figure 1. The January flights were flown as far north as Cape Christian on Baffin Island to ensure a total census of the area. The late February/early March Preseason revealed only 303 icebergs south of Cape Dyer with no bergs below 48°N, Figure 4. This was far below statistical normals and lead to the expectation of another light season. Figures 30a through 30l show normal and 1976 surface pressure patterns for November through August. The isobars, shown as heavy solid lines, provide an indication of average wind direction for a given month in our area of concern. Winds tend to blow nearly parallel to the isobars, counterclockwise for a low and clockwise for a high in the Northern Hemisphere.

During the early part of the season, approximately November through mid-April, the predominant map feature was an abnormally positioned and unusually intense Icelandic Low. This deviation produced strong to moderate surface winds from the west and west-northwest south of 52°N. With these winds and the resulting wind-driven currents, bergs approaching the Grand Banks were driven to the east out of the core of the Labrador Current. This essentially ended any further southward drift of this ice and scattered the bergs eastward around the Flemish Cap.

The low upstream iceberg inventory and offshore winds were the main reasons for the below normal counts of icebergs crossing 48°N in April.

During May, the Icelandic Low appeared much more intense than normal and was centered north-northeast of its usual position. This caused the prevailing winds to shift, coming from the northwest, and by late May bergs were again drifting south in the Labrador Current along the eastern slope of the Grand Banks.

As has been normal, average winds were onshore during June and for the remainder of the season, inhibiting any further iceberg drift onto the Grand Banks.

Surface pressure gradients (differences in atmospheric pressure along a geographically oriented line) provide an indication of wind velocities that exist in the area. The steeper the gradients, or the more rapid pressure change, the higher the wind speed will be. In an attempt to understand the magnitude and primary direction of winds along the main routes of icebergs heading toward the Grand Banks, six such gradients have been defined by Ice Patrol for Davis Strait and certain areas off the Newfoundland and Labrador coasts (Figure 31). From an analysis of these gradients, inferences can be made about the northwesterly winds producing southerly iceberg drift, accentuating the Labrador Current, reducing the air and sea temperatures and developing and spreading sea ice along the coasts of Labrador and Newfoundland.

Gradients assigned numbers 1 and 2 in Figure 31 indicate the intensity of the north/south components of the winds off the Labrador coast. These winds are important in assisting or impeding the drift of icebergs toward the Grand Banks.

Gradient 3 measures the north/south wind component along the eastern slope of the Grand Banks which is partially responsible for determining the speed at which icebergs will drift south in this area. Gradient 4 is a measurement of the influence of westerly, or easterly, winds along the northern slope of the Grand Banks. These winds are important in determining iceberg drift toward or away from the Newfoundland coast and into or out of the core of the Labrador Current. If the westerly winds are too strong or persistent when the bergs reach the northeast corner of the Grand Banks, they may be carried over Flemish Cap and deteriorate rapidly as they are pushed into the warmer waters of the North Atlantic Current. Gradients 5 and 6 provide a preseason indication of the potential for iceberg drifts south and west in Davis Strait.

The 1976 pressure gradient statistics are shown graphically in Figure 32 in comparison with their 1946–1975 averages. Gradients 1 and 2 show above normal southerly flows throughout the season, with lulls in the December, January and April positions of each graph before normalizing or going slightly below normal in July. This provided a great impetus for southerly iceberg drift during the season. Icebergs did not reach gradient areas 3 and 4 until early March. From then until mid-June, the gradient pressure rose to slightly above normal, thereby increasing southerly flow slightly. Gradient 4 shows a predominant easterly wind flow until mid-June, which kept the bergs drifting mainly in the Labrador Current along the eastern slope of the Grand Banks. Gradients 5 and 6 combined show a general south-easterly flow, from September through November, then changing to a predominant northerly flow inhibiting berg movement into the Davis Straits until February when both gradients basically normalized.

Air temperatures throughout the season were normal with the exception of northern Labrador and Baffin Island where temperatures fell to approximately 6–8°F below normal in January and February. A frost degree day, as used in Figure 33, is defined as one day at a temperature of one fahrenheit degree below 32°F i.e. one day at 20°F would be 12 frost degree days). Similarly, a melting degree day is one day at a temperature of one fahrenheit degree above 32. All stations illustrated showed slightly above normal frost degree days and slightly below normal melt degree days. These near normal temperatures combined with the far less than normal southern expanse of sea ice this year were in a large part responsible for limiting the number of icebergs that survived to reach the Grand Banks region, resulting in a relatively light season.

Figures 34 and 35 depict sea surface temperature (°C) contours for two representative periods during 1976. Contours provided by the Meteorology and Oceanography Office (METOC) of Canadian Maritime Command (MARCOM) have been modified by additional data received by Ice Patrol from merchant shipping and Airborne Radiation Thermometer (ART) surveys. Since the latter part of the 1974 ice season, Ice Patrol observers have been using the ART to record sea surface temperatures while conducting aerial ice reconnaissance. The operational use of the ART has been described in Appendix C of the 1974 Ice Patrol Bulletin (CG–188–29) and is discussed further in Appendix E of this Bulletin. The late April temperatures in 1976 were just slightly warmer than normal and early July sea surface temperatures were approximately 1°C below normal. This corresponds well with the melt degree day records for St. John's presented in Figure 33 showing April's accumulation greater than normal and both June and July's below normal.

The following iceberg melt table was developed from observations made by Lenczyk (1962–1964). The International Ice Patrol uses this table to predict the complete melt of various sized icebergs.

Temperature (°)	*Growler and Small Iceberg (Height 1–15m Length 6–60m*	*Medium Iceberg (Height 16–45m Length 61–122m)*	*Large Iceberg (Height 46+ meters Length 123+ meters)*
0	—	—	—
2	9 days	17 days	38 days
4	6 days	11 days	23 days
6	4 days	8 days	16 days
8	3 days	6 days	13 days
10	3 days	6 days	11 days
12	3 days	5 days	9 days
14	2 days	4 days	8 days

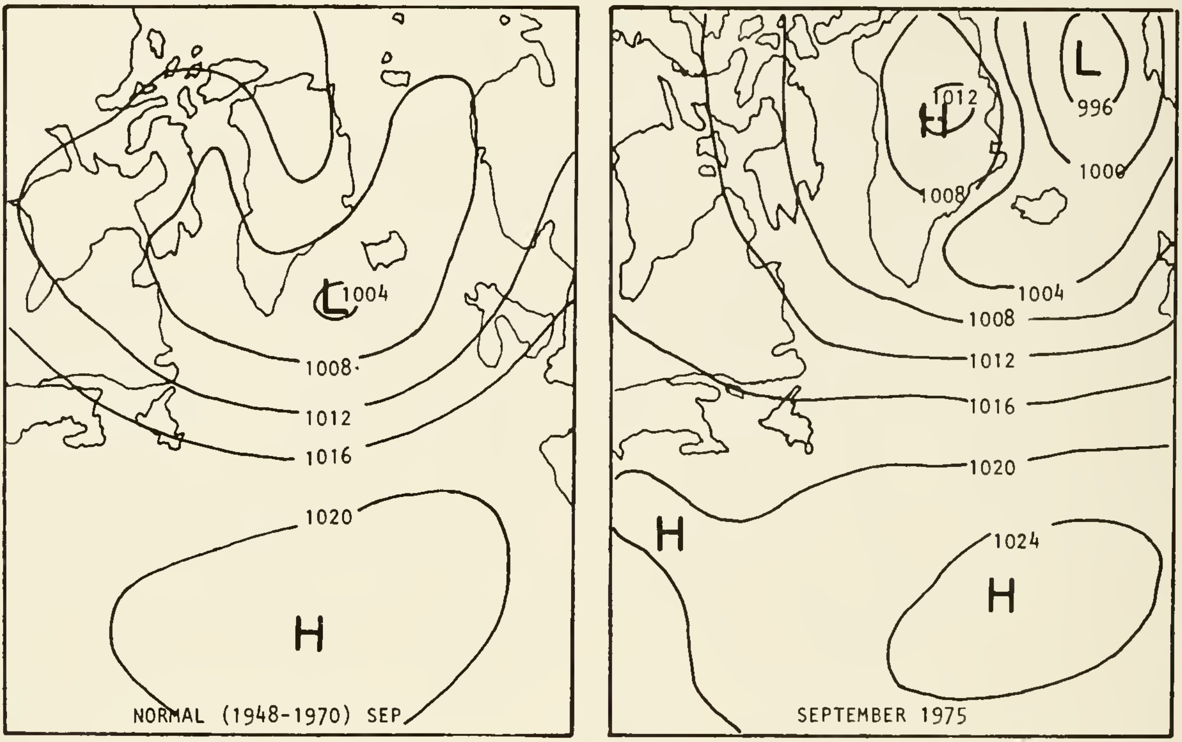


Figure 30a.—September Normal and 1975 Monthly Average Surface Pressure in mbs

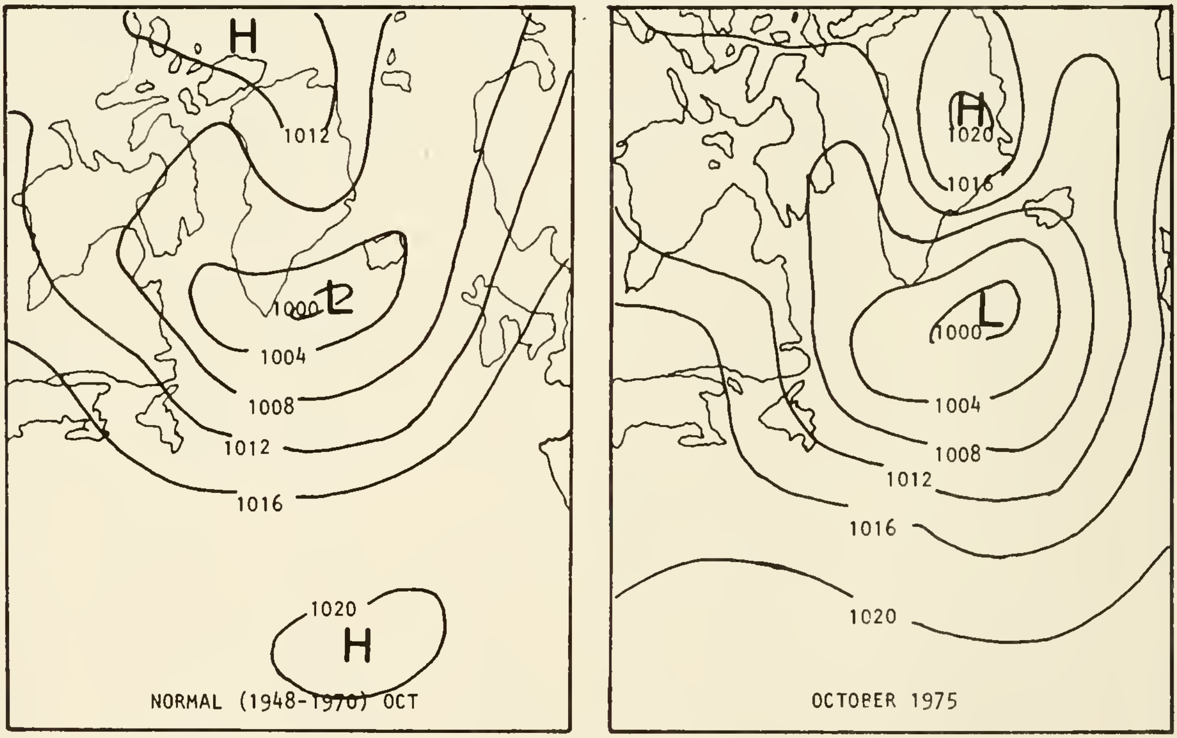


Figure 30b.—October Normal and 1975 Monthly Average Surface Pressure in mbs

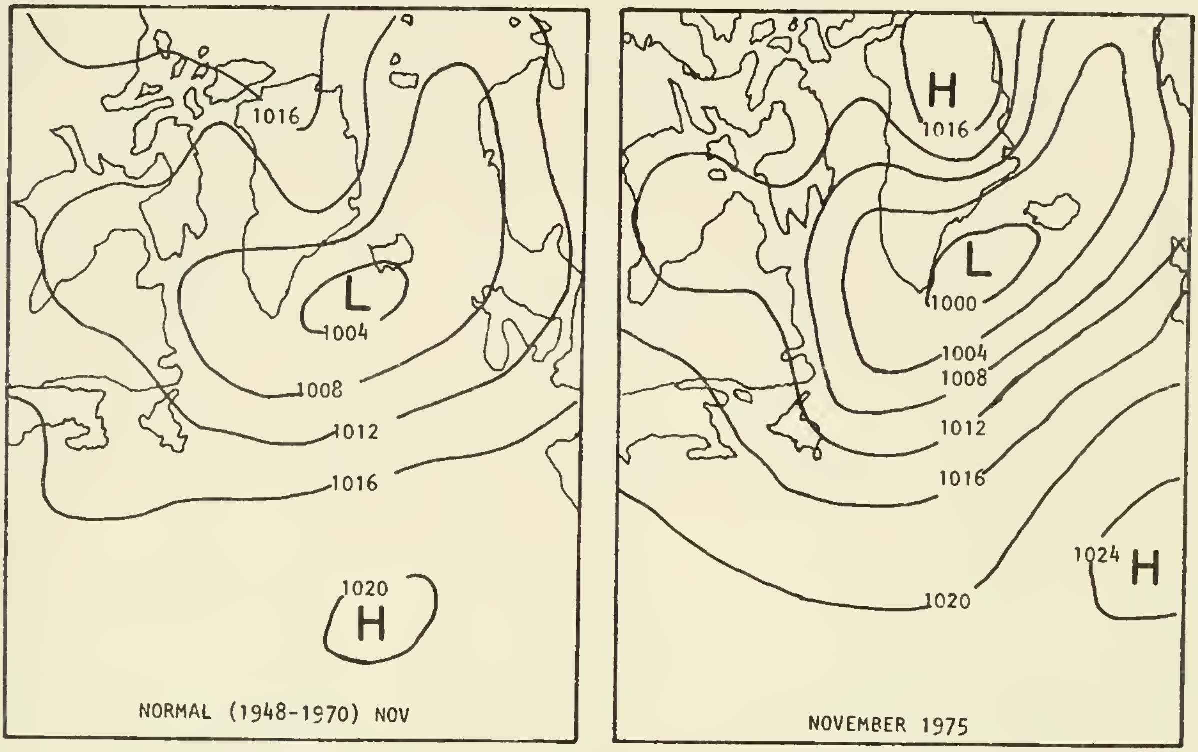


FIGURE 30c.—November Normal and 1975 Monthly Average Surface Pressure in mbs

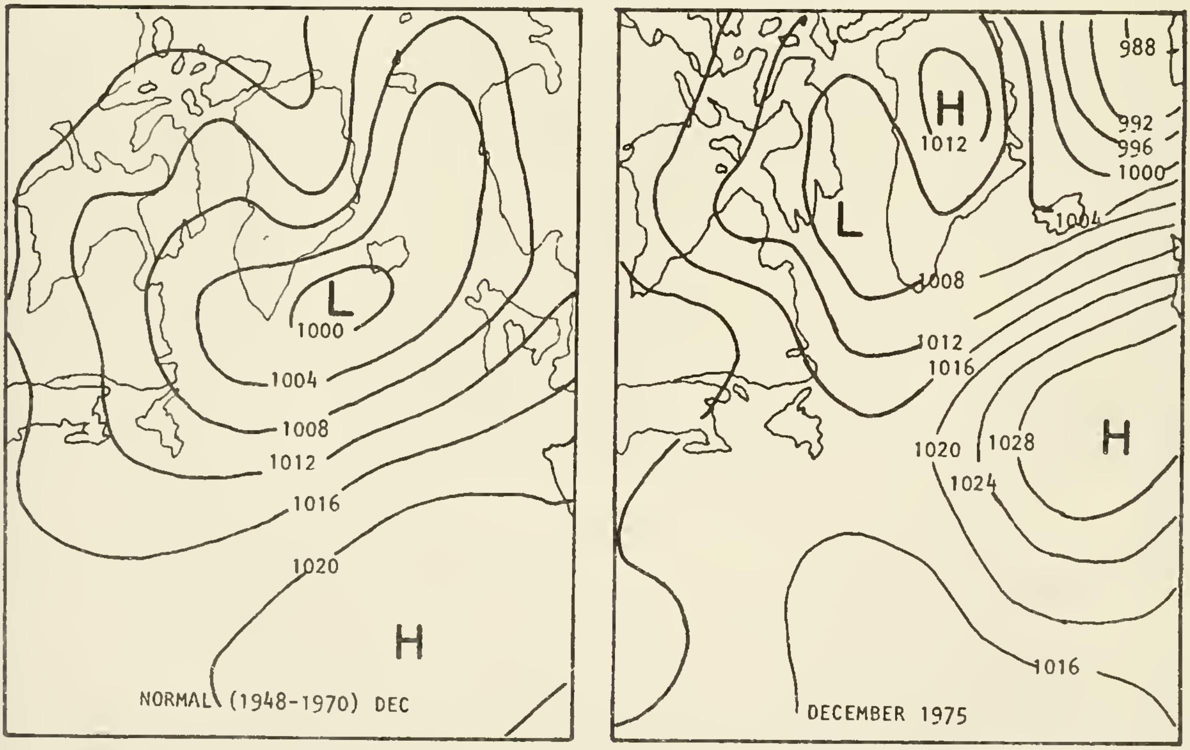


FIGURE 30d.—December Normal and 1975 Monthly Average Surface Pressure in mbs

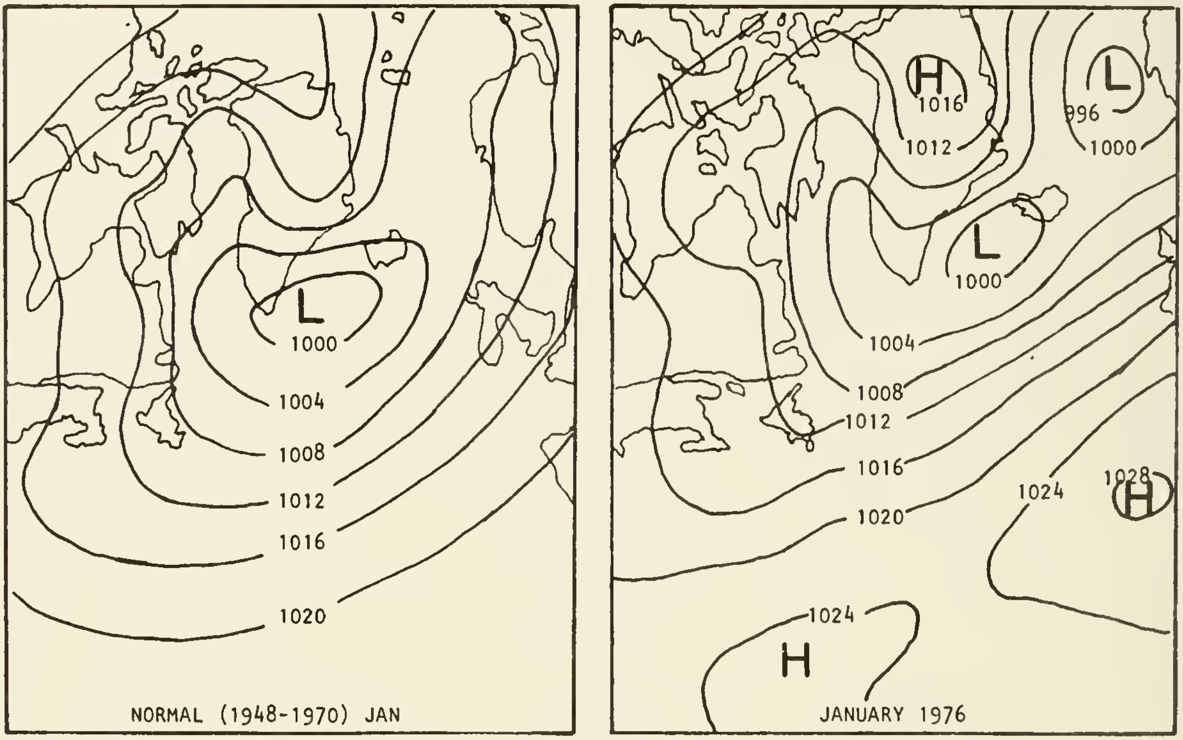


FIGURE 30e.—January Normal and 1976 Monthly Average Surface Pressure in mbs

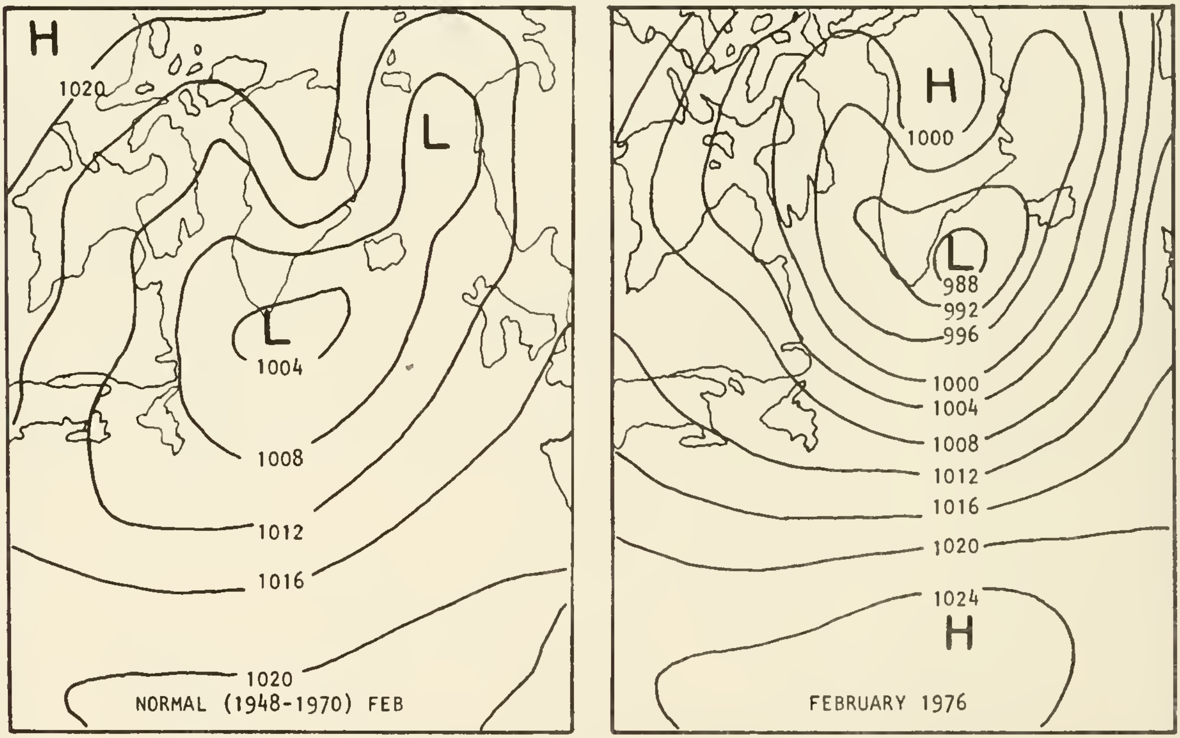


FIGURE 30f.—February Normal and 1976 Monthly Average Surface Pressure in mbs

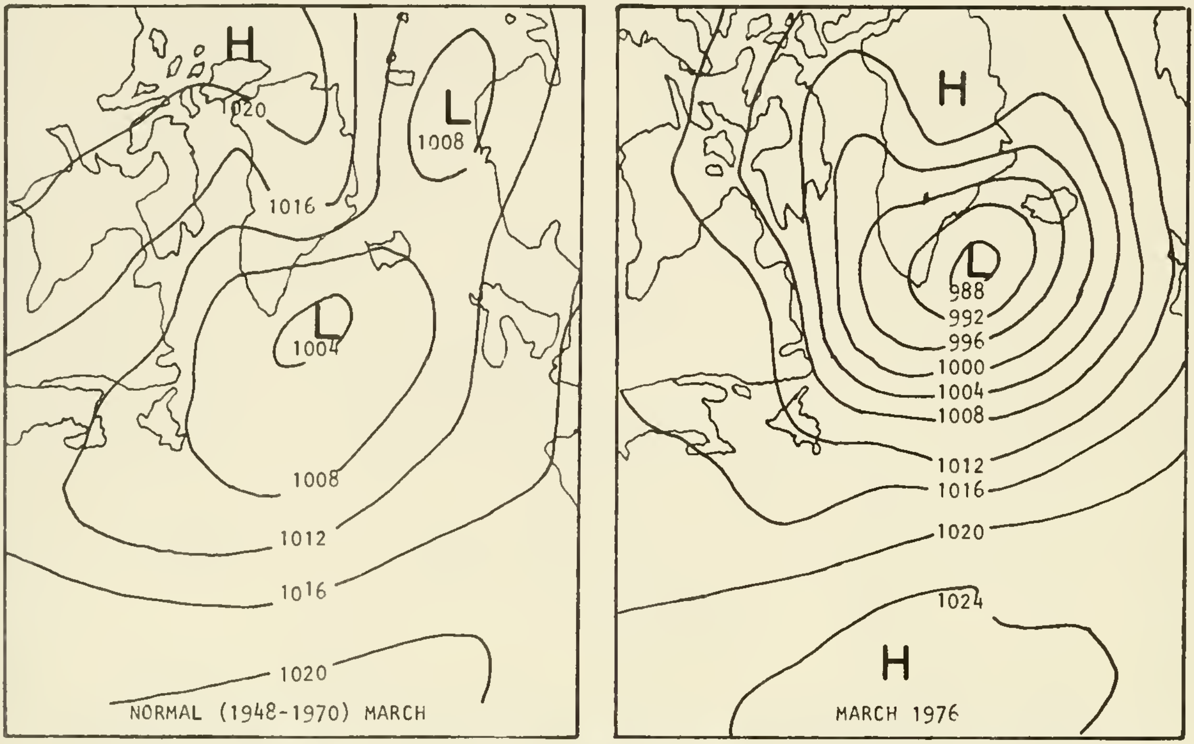


Figure 30g.—March Normal and 1976 Monthly Average Surface Pressure in mbs

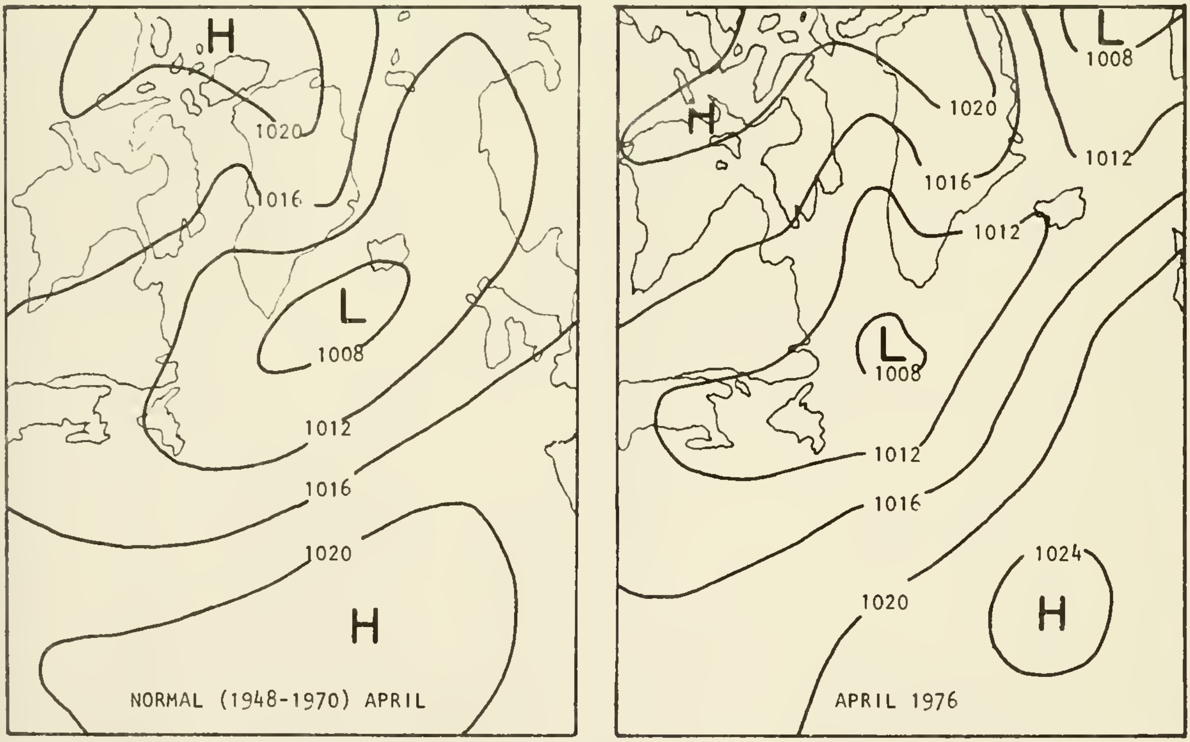


Figure 30h.—April Normal and 1976 Monthly Average Surface Pressure in mbs

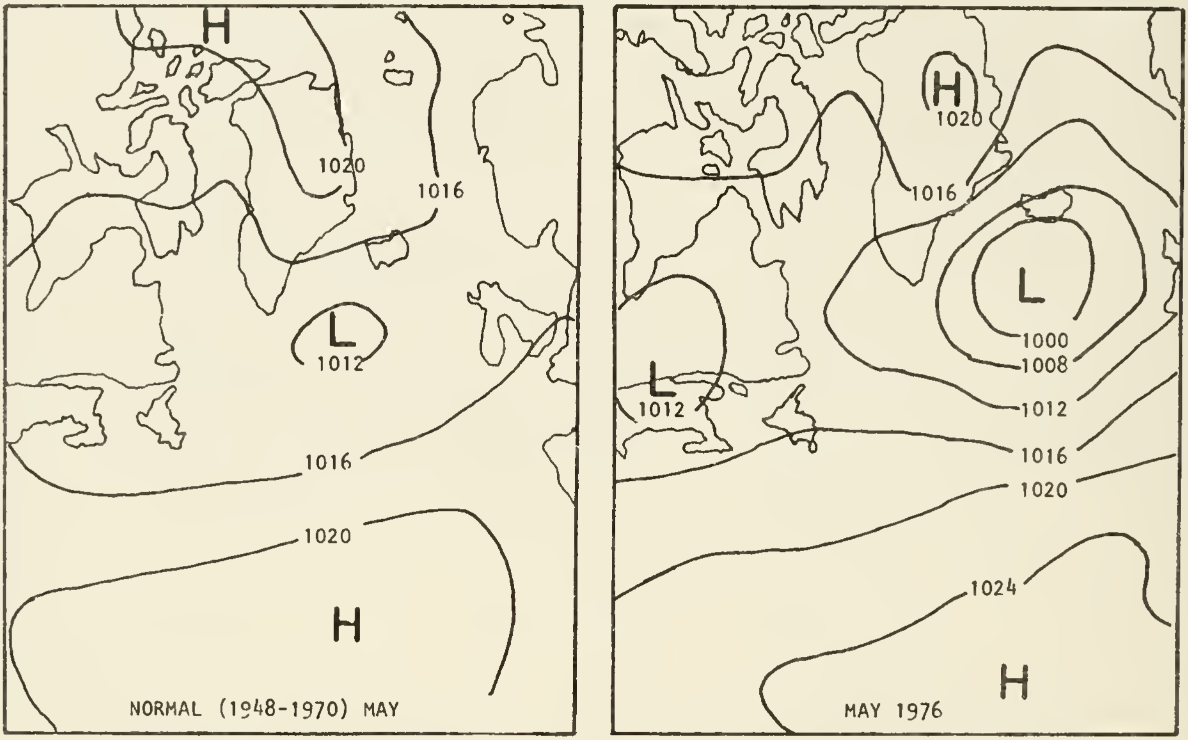


Figure 30i.—May Normal and 1976 Monthly Average Surface Pressure in mbs

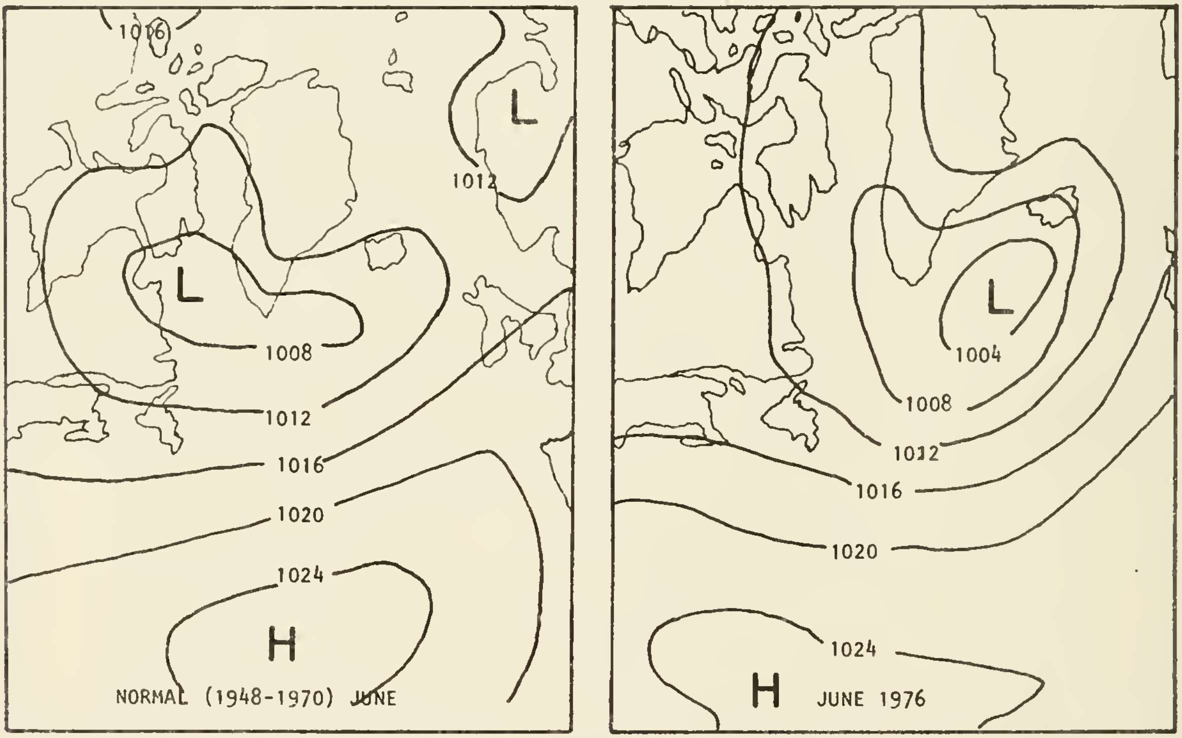


Figure 30j.—June Normal and 1976 Monthly Average Surface Pressure in mbs

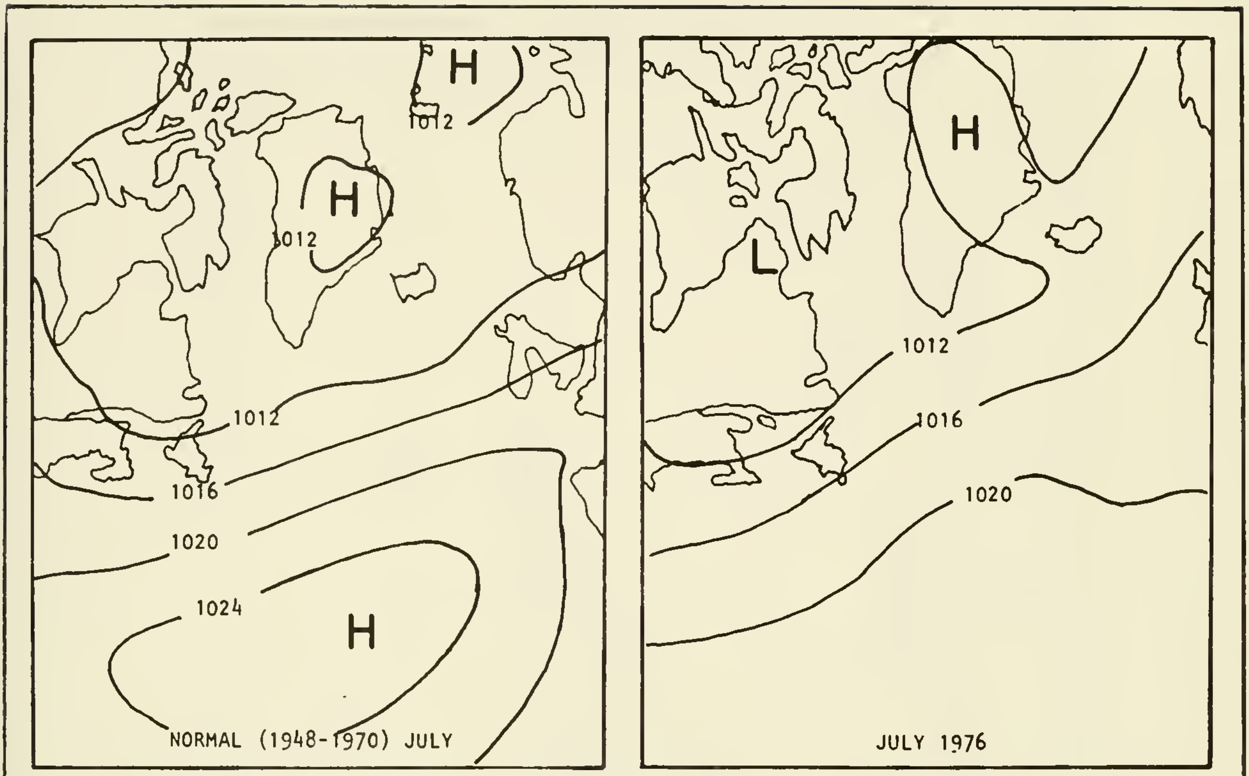


FIGURE 30k.—July Normal and 1976 Monthly Average Surface Pressure in mbs

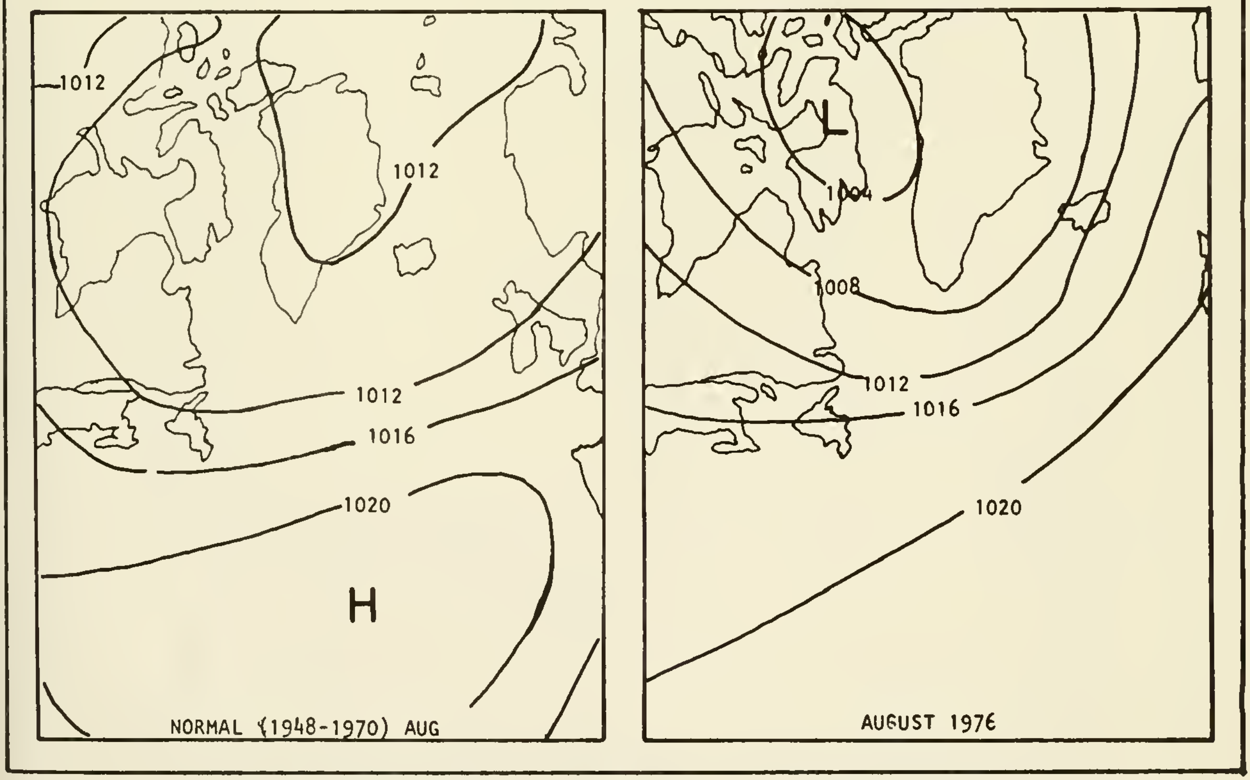


FIGURE 30l.—August Normal and 1976 Monthly Average Surface Pressure in mbs

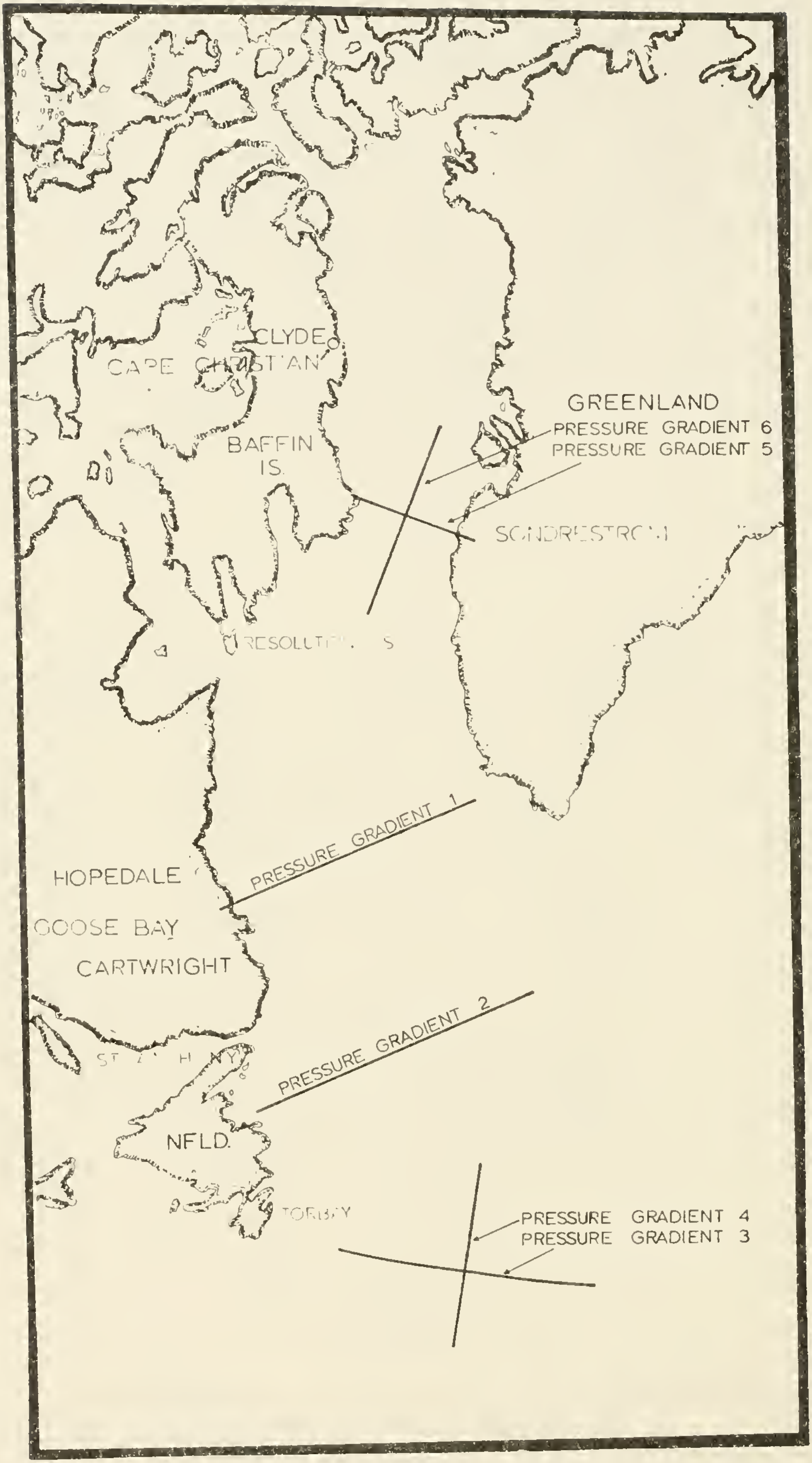


FIGURE 31.—Pressure Sections Monitored by the International Ice Patrol

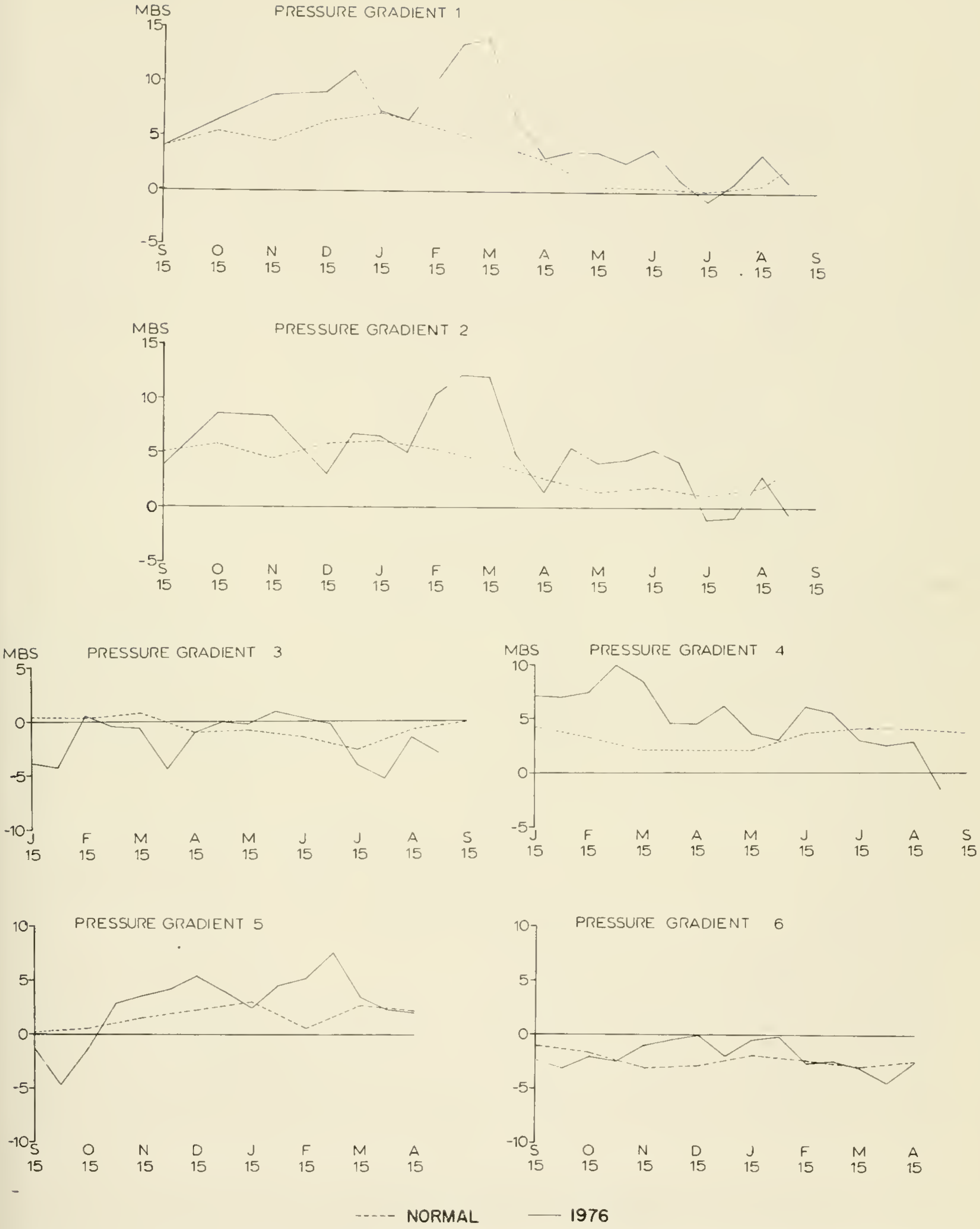


Figure 32.—Comparison of the Normal Pressure Gradient to those recorded during the 1976 ice season on Section 1 thru 6

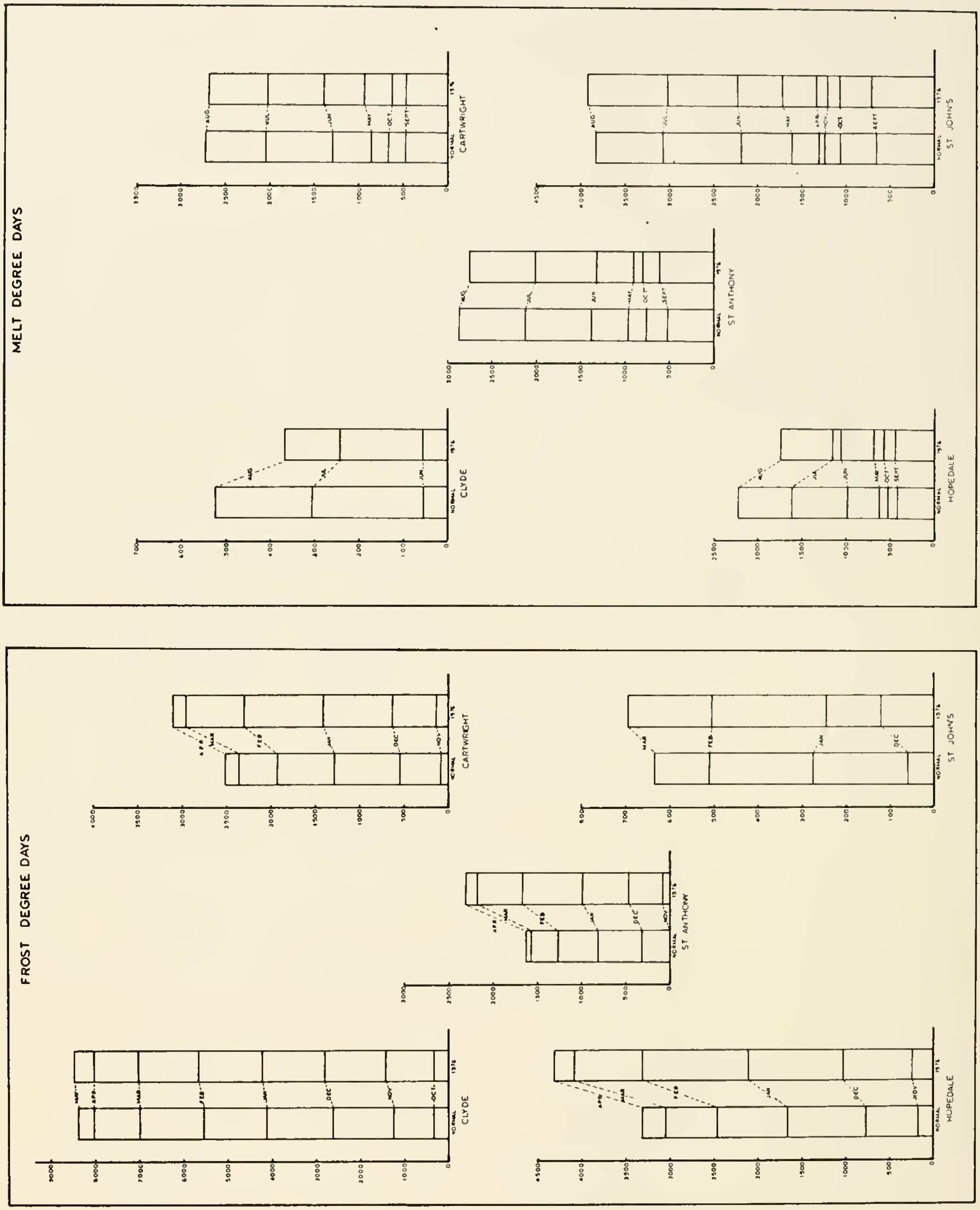


FIGURE 33.—Frost Degree Day and Melt Degree Day Accumulations Calculated from Monthly Mean Fahrenheit (°F) Air Temperatures

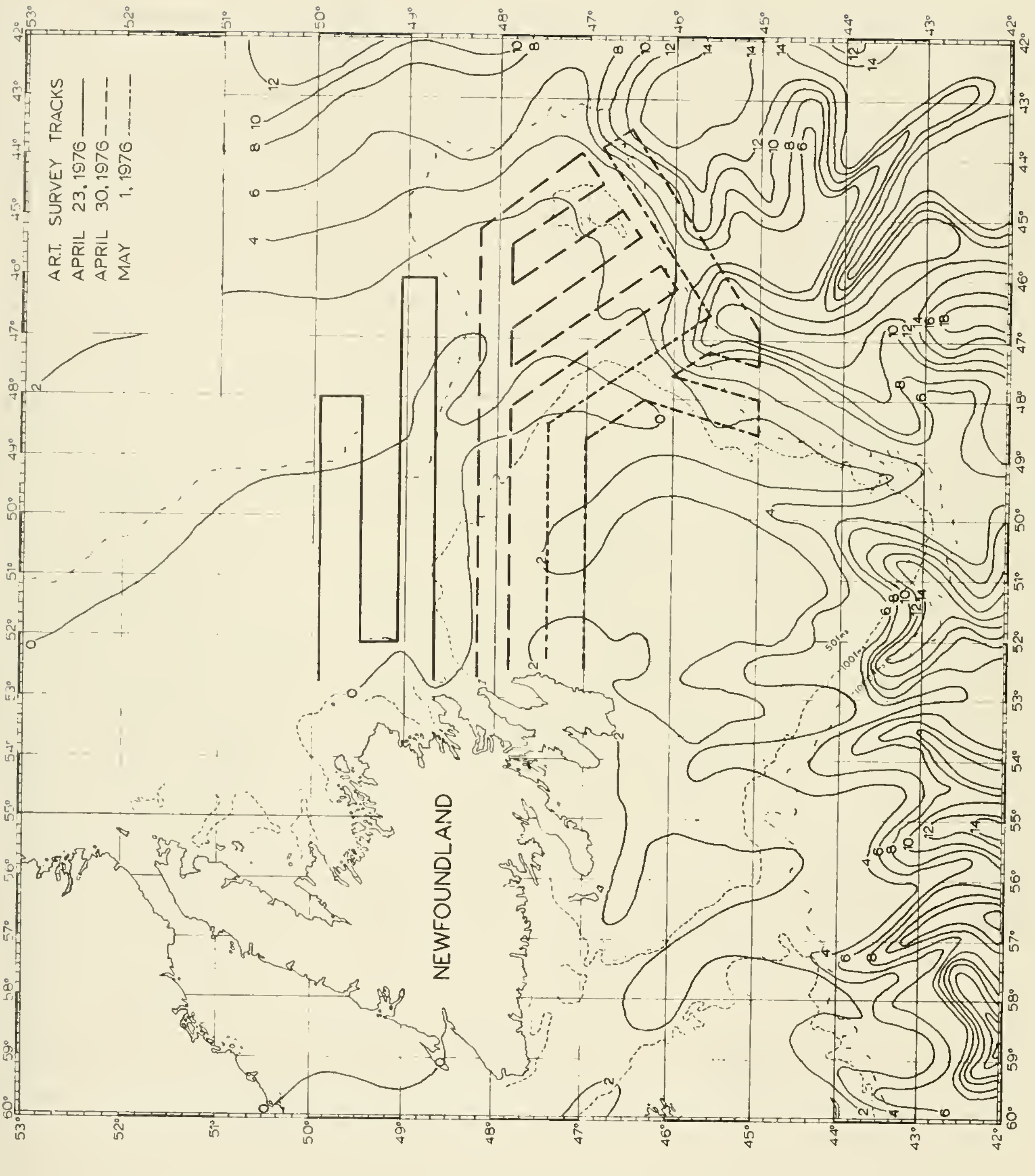


FIGURE 34.—Sea Surface Temperature Contours (°C) developed from Airborne Radiation Thermometer (ART) surveys conducted on 23 and 30 April and 1 May 1976

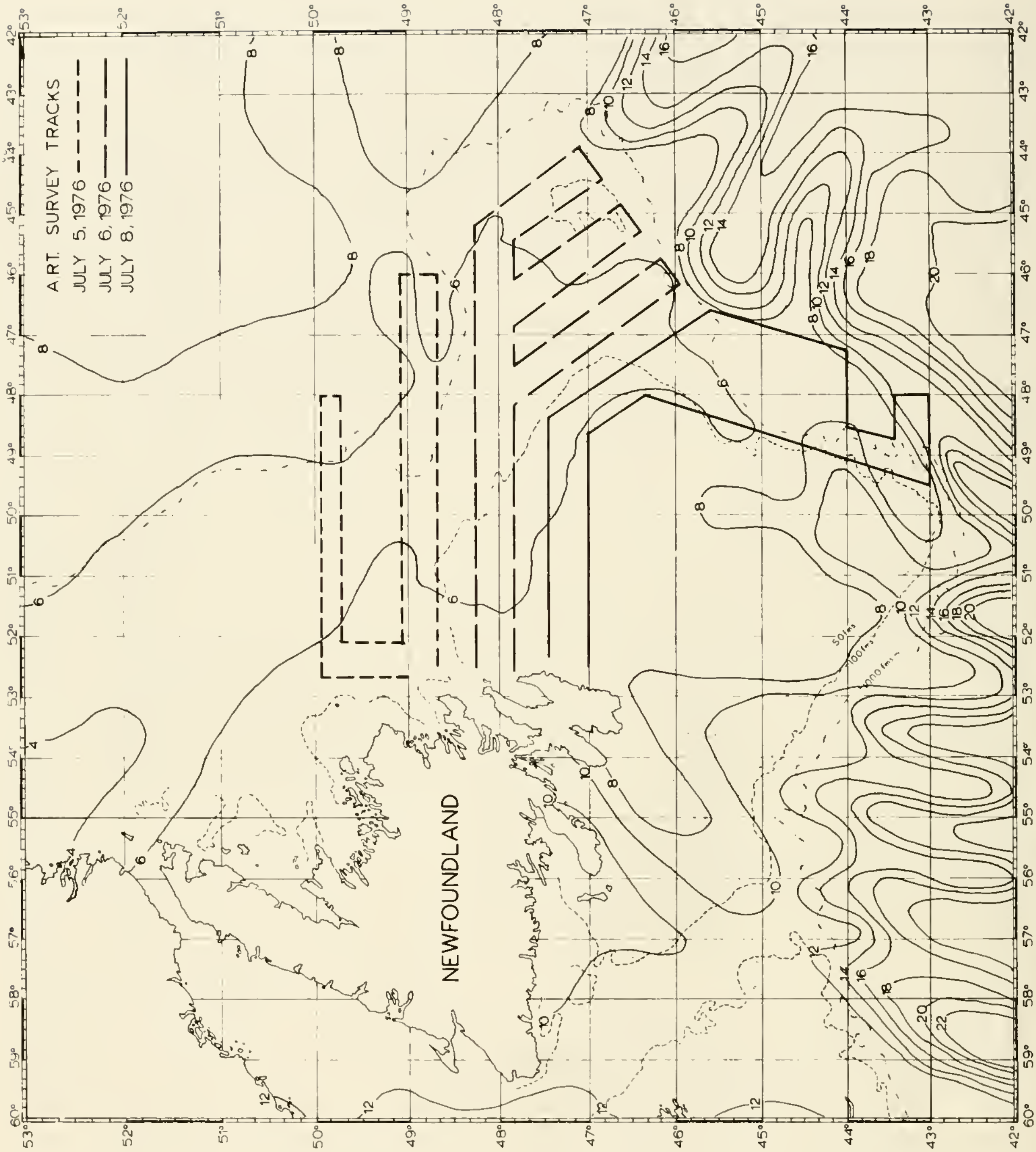


FIGURE 35.—Sea Surface Temperature Contours (°C) developed from Airborne Radiation Thermometer (ART) surveys conducted on 5, 6 and 8 July

RESEARCH AND DEVELOPMENT, 1976

During 1976, the IIP research and development effort was centered on the collection of iceberg drift date, gathering of current information near the Tail of the Banks, and further development of remote sensing equipment.

The iceberg drift data endeavor was designed to provide the velocities of the iceberg, current and wind. Current velocity was obtained by using a newly designed integrating current drogue. The drogue made use of multiple window shade drogue panels to measure the total current affecting the iceberg. The surface float/marker used a newly acquired X-Band radar transponder which marked the radar screen with a unique symbol for easy identification. Detailed drifts were obtained for time periods up to 60 hours.

An unsuccessful attempt was made to measure the current field east of the Tail of the Banks. Three moorings at the corners of an equilateral triangle were to provide information on eddies, meanders and rings of the Labrador/North Atlantic Current system. The moorings were deployed without difficulty, but were not recovered due to an unknown equipment malfunction.

A photographic survey of Grand Banks icebergs was conducted with an aerial mapping camera. One result of this survey was a series of fine photographs of the same tabular iceberg over a time period of 24 days (See Appendix B). The deterioration processes acting on the iceberg were clearly evident.

Remote sensing test and evaluation was conducted with the continuation of a cooperative NASA Lewis Research Center-International Ice Patrol program to develop an all-weather iceberg detection and identification system. Side-Looking Airborne Radar (SLAR/APS–94C) was the primary instrument used and was found to be an extremely reliable detection device. The problem remains with identification of the detected targets (i.e., ship vs. iceberg, surface debris vs. iceberg, sea ice vs. iceberg). Attempts were made to use ECM (Electronic Counter Measure) equipment. It was hoped that the ECM would be able to detect shipboard radar transmissions and thus identify certain targets as ships. Problems in accurately determining the direction from which signals originated and the realization that a number of ships, particularly fishing vessels, often operated without radar, proved to make this system unreliable. SLAR remains the device providing the most potential for solving Ice Patrol's problems of tracking icebergs in the adverse weather conditions so prevalent in the vicinity of the Grand Banks.

Over-the-Horizon Radar (OHR) was evaluated for iceberg detection using the MADRE system of the Chesapeake Naval Research Laboratory. It was determined that the present state-of-the-art does not provide sufficient resolution to meet the need of the Ice Patrol.

ICE AND SEA SURFACE TEMPERATURE REPORTS RECEIVED FROM SHIPS OF PARTICIPATING NATIONS DURING 1976

	ICE	SST
BELGIUM		
FEDERAL SCHELDE	2	
FEDERAL ST LAURENT	1	
CANADA		
HURON		6
IMPERIAL QUEBEC	2	
NIPIGON		18
CHILE		
CHOAPA	2	2
DENMARK		
AVALON	1	
LOUIS MAERSK	1	
NINA LONBORG	1	
NORTHERN	1	
PACIFIC SKOU	1	
ROSA DANIA	1	
SAMOAN REEFER	1	
TORM ESTRID		1
EAST GERMANY		
ALSTER EXPRESS	1	
BETAGAS	1	
BRUNSWICK		12
ELBE EXPRESS	1	
NORDIC	1	
PROSERPINA		1
THOR	1	
TILLY ROSS	1	
FINLAND		
FORANO		9
FRANCE		
DELCHIM ALSACE		5
FRANCOIS L D	1	
GREAT BRITAIN		
ALBRIGHT PIONEER	1	
ALTENOR	1	2
ARCTIC TROLL	1	3
ARDMORE		4
ATLANTIC CAUSEWAY	1	
ATLANTIC CONVEYOR	1	

	ICE	SST
GREAT BRITAIN—Continued		
BRIMNES		3
CAST BEAVER	1	
C P DISCOVERER	5	
C P TRADER	14	
C P VOYAGUER	3	
DART AMERICA	2	1
DART ATLANTIC	1	1
ESKDALEGATE		28
FRINTON	1	
KING CHARLES	1	
KING JAMES	1	
MANCHESTER CHALLENGE	3	
MANCHESTER CONCORDE	10	7
MANCHESTER CRUSADE	1	
MONKSGARTH	1	
M S LAURENTIAN	1	
QUEEN ELIZABETH	2	
QUEENSGARTH	4	
RESOURCE		1
SILVERTWEED	1	
SUGAR TRANSPORTER	1	1
VANCOUVER TRADER	2	
GREECE		
ALTHEA	1	
NIKOT	1	
ICELAND		
BAKKAFOSS	10	56
BRUARFOSS	2	1
SELFOSS	3	1
ITALY		
GALLASSIA		5
LEONARDO DA VINCI		1
JAPAN		
EUROPEAN HIGHWAY	1	
KOREA		
WHITE ROSE	1	
KUWAIT		
AL ARIDHIAH	6	

	ICE	SST
LIBERIA		
ARTADI		8
ASIA FLAMINGO		1
FALCONDALE	1	
GARDEN SUN		7
GLORIC	1	
KONKAR INTREPID		1
MASTER JANEY	1	
MELTIMI		7
OGDEN CLIPPER	1	
OGDEN THAMES	1	
ORE METEOR		1
NETHERLAND		
ANTARCTIC	1	
DORDRECHT	1	
THUREDRECHT	2	
WITTI ZEE	1	
NORWAY		
BANAK	1	
BELCARGO	1	
BRUNHORN	1	
FALCON	1	
FERNLEAF		2
GARD	1	5
HANSA BAY	1	
IDEFJORD	2	
JAWAGA	1	
JOADA	1	
JOBEBE	1	
PANAMA		
HUMBERT	1	
PARAGUAY		
PEKARI	1	
POLAND		
STEFAN BATORY	1	
ZAMBRZE	2	
SENEGAL		
PAN TECK		5
SINGAPORE		
ANDROMED	1	
KONKORDIA	1	
SWEDEN		
ARIEL	1	
ATLANTIC SAGA		3
ATLANTIC SPAN		31
GUNNAR CARLSON	1	
IRISH WASA		6
MILES	1	
MONTROYAL	19	1
RAGNA GORTHON		4
SEGERO	1	
UNITED STATES OF AMERICA		
KNORR	2	
NEPTUNE		3
PIEDMONT		3
PUGET SOUND		5
UNITED STATES COAST GUARD		
USCGC EVERGREEN	15	1406
USCGC NORTHWIND	95	110
USCGC SHERMAN	33	26
USCGC WESTWIND	3	1
UNITED STATES NAVY		
USNS MIRFAK	1	1
WEST GERMANY		
ANTARES	6	
TUBINAR		1
YUGOSLAVIA		
BOSANKA NO. 1		6

APPENDIX A

SIZE FREQUENCY DISTRIBUTION OF GRAND BANKS ICEBERGS

R. Q. ROBE

U.S. Coast Guard Research and Development Center

Historically, iceberg counts have been made by an IIP estimate of the total number of iceberg and growlers along the eastern Canadian coast and the Grand Banks. Of necessity, very little attention was given to the accurate determination of size. Tabular icebergs were categorized (Murray, 1968) as large (height greater than 50 ft.; length greater than 700 ft.), medium (height 20–25 ft.; length 300–700 ft.) and small (height to 20 ft.; length less than 300 ft.). All shapes other than tabular were categorized as very large (height greater than 255 ft.; length greater than 700 ft.), large (height 150–255 ft.; length 400–700 ft.), medium (height 50–150 ft.; length 200–400 ft.), small (height less than 50 ft.; length less than 200 ft.). Although the ice observers are highly trained, their estimates are subjective. They must rely only on a practiced eye to place a berg in one of the above categories. This requires that they estimate range to the berg and then evaluate its relative size against a background of ice or water, neither of which offer any known object for size comparison. This estimation is conducted at various flight levels, sun angles, and visibilities. As a result, size estimations result in a poor quantitative size distribution and are not useful for a detailed study of iceberg sizes.

With the advent of remote sensing possibilities for iceberg detection, a more quantitative distribution for iceberg sizes is needed. In order for such systems as SEASAT and SLAR (Side-Looking Airborne Radar), with their greater all weather detection capability, to be used to full advantage, information on the population they are sampling must be available.

During the 1976 IIP season a CA–14 aerial mapping camera was placed aboard the Ice Patrol aircraft for a period of 47 days. On these flights, a total of 104 icebergs and growlers were photographed. Altitudes for the photographic flights ranged from 1,000 ft. to 11,000 ft. The area covered by the photographed icebergs was between 44°N and 51°N and 45°W and 51°W. Icebergs were photographed on a not to interfere basis with the aircraft's primary mission of iceberg reconnaissance. Therefore, the sample does not represent the totality of icebergs in the area covered. Growlers of less than $10m^2$ were not counted.

The frequency of icebergs versus horizontal cross-sectional area (Figure A–1) indicates a very strong peak for the small sizes. Icebergs less than $1{,}000m^2$ (but greater than $10m^2$) account for 53 of the 104 icebergs in the sample. The frequency drops off rapidly as size increases. Icebergs in the interval $1{,}000m^2$ to $2{,}000m^2$ included only 12 icebergs and the range $2{,}000m^2$ to $6{,}000m^2$ 22 icebergs. Only 17 of the 104 icebergs were larger than $6{,}000m^2$.

SEASAT-A which is due to be launched in 1978 will carry a SAR (Synthetic Aperature Radar) with a resolution of approximately 25m. This resolution should make it possible to distinguish icebergs with a horizontal cross-sectional area of greater than $1{,}000m^2$ from ships and debris. In the present sample, slightly more than 50% of the icebergs and growlers are smaller than the $1{,}000m^2$.

Data collection will continue over the next several years to build an accurate base of information on iceberg sizes as a function of both season and geographic area.

REFERENCE

Murray, J. E., The Drift, Deterioration and Distribution of Icebergs in the North Atlantic Ocean (Ice Seminar: A Conference Sponsored by the Petroleum Society of CIM, Calgary, Alberta, May 1968.)

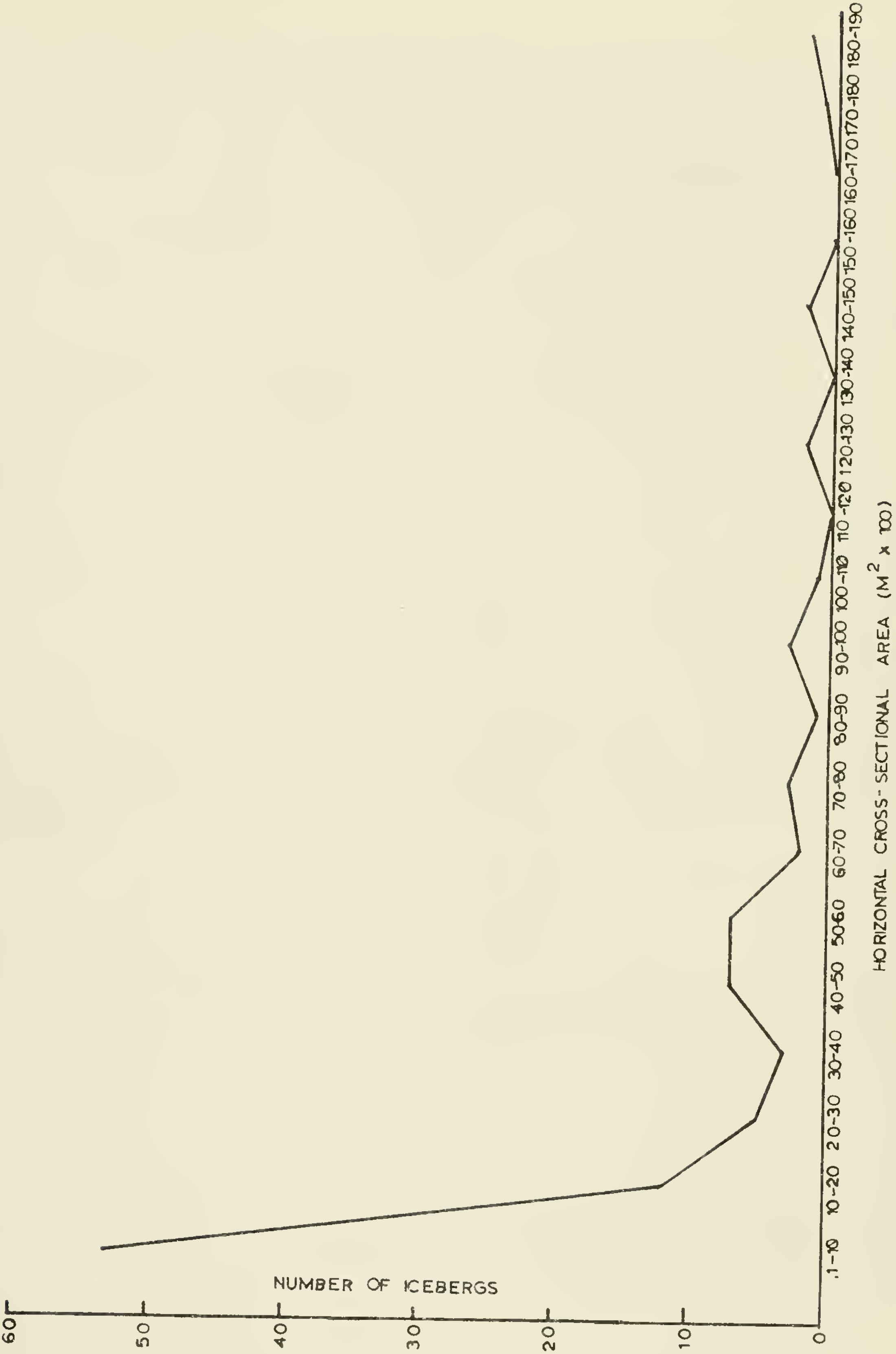


FIGURE A-1.—Size frequency distribution of icebergs, located in the vicinity of the Grand Banks of Newfoundland (1976).

APPENDIX B

ICEBERG DETERIORATION

R. Q. ROBE and D. C. MAIER, MST2, USCG
U.S. Coast Guard Research and Development Center
and
R. C. KOLLMEYER, CAPT, USCG
U.S. Coast Guard Academy

A very large tabular iceberg was observed as it drifted northeast of the Grand Banks of Newfoundland during May and June 1976. When the iceberg was first sighted on 12 May 1976, it showed only minor signs of deterioration. From 12 May until last sighted on 6 June, the iceberg underwent a rapid reduction of the above water surface area with the erosion largely confined to the turbulent layer associated with gravity waves. The erosion progressed along lines parallel to the structure of the iceberg as indicated by the pronounced ridge pair seen in the photographs (Figure B–1), a trellis drainage pattern, and an alternation of light and dark bands over the entire surface of the iceberg.

Photographs were taken of a large number of icebergs during the 1976 flights of the International Ice Patrol. These photographs are to be used for a study of iceberg populations off the Grand Banks (Figure B–2). Black and white photographs (9-inch format) were taken from altitudes of between 300 and 3500 m.

Among the photographs obtained are a unique series of five taken of the same iceberg over a period of 25 days (Figure B–1). It is highly unusual for an iceberg to be relocated over such an extended period when positive identification is possible. Icebergs normally change their appearance so radically by a combination of calving, melting and rolling, that it is impossible to positively identify them after only a few days. In this case the unusually low profile, only 4–5m of evaluation, and tabular shape maintained the iceberg in an extremely stable condition.

From 12 May to 6 June 1976 the iceberg decreased in surface area from approximately 190,000m^2 to an area of 109,000m^2. The rate of decrease in surface area was nearly linear (Figure B–3) and resulted from wave erosion, undercutting and minor calving. The surface water temperature was 2–4°C. Subsurface temperatures in this area typically decrease to a minimum of less than -1°C at 75–100m depth.

Wave erosion was concentrated at those points which appear as slight irregularities in the 12 May 1976 photograph. The progressive enlargement of these embayments was the result of the local concentration of wave energy and continued bathing of the ice by the turbulent water. The embayments seemed to extend only several meters below the water's surface and have an orientation parallel to the structural features of the iceberg. The underwater shape of the iceberg is not known but it is suspected to have had a flat bottom as inferred from the long-term maintenance of its top parallel to the sea surface.

The iceberg seemed to be of land ice origin. Analysis of a piece of the iceberg, recovered by the USCGC EVERGREEN, showed it to be fresh water ice. The characteristic air bubble bands of glacier ice were visible and surface melt tests produced a pattern of hexagonal depressions approximately 2cm across which typify the crystalline melt surface texture of glacier ice. The two linear parallel ridges in the upper third of each picture of Figure 1 are the most obvious manifestations of the ice structure. In the original photographic prints, a pattern of trellis drainage can be seen which indicates structural

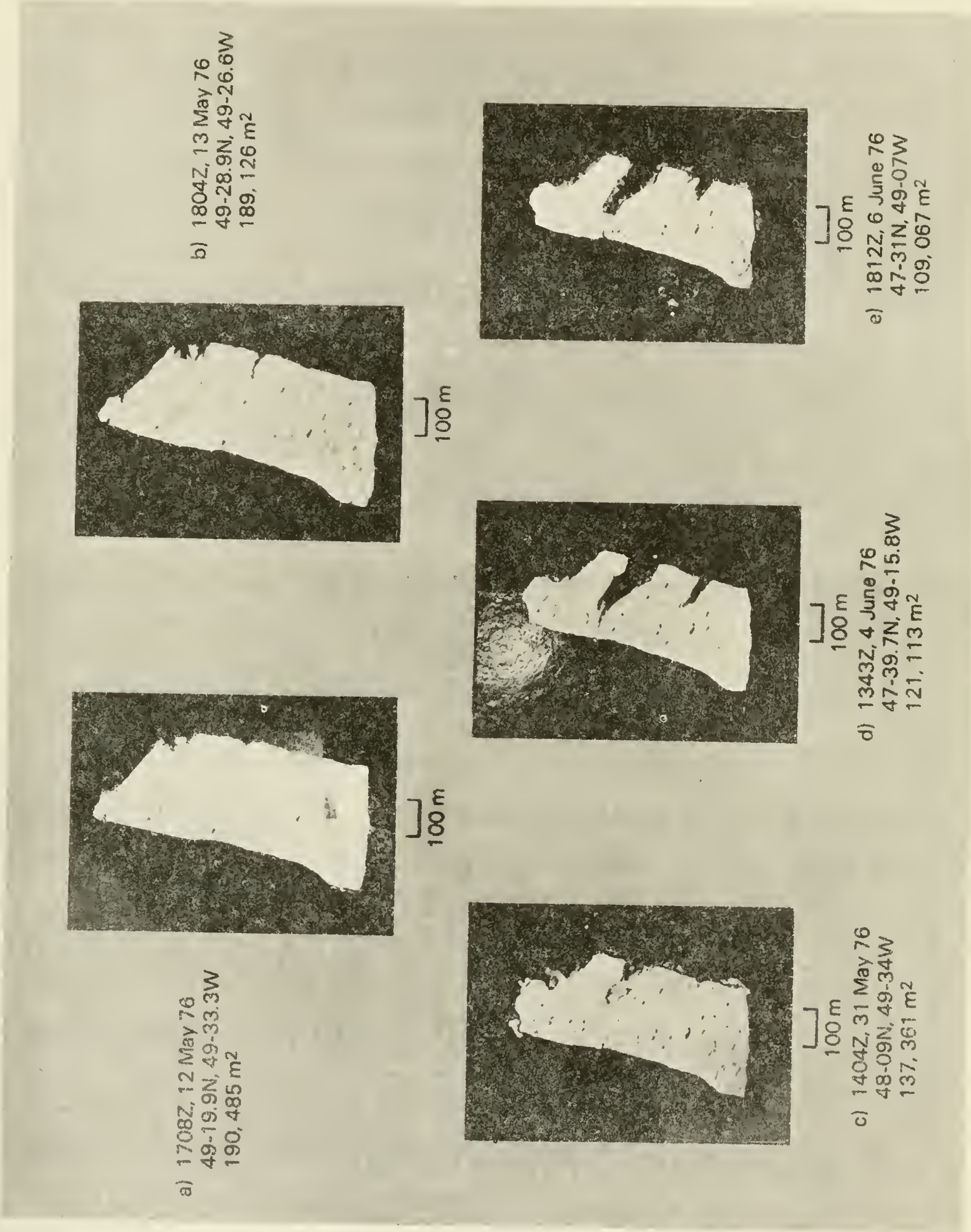


FIGURE B-1.—Time Series photographs showing the deterioration of an iceberg and the progressive enlargement of embayments.

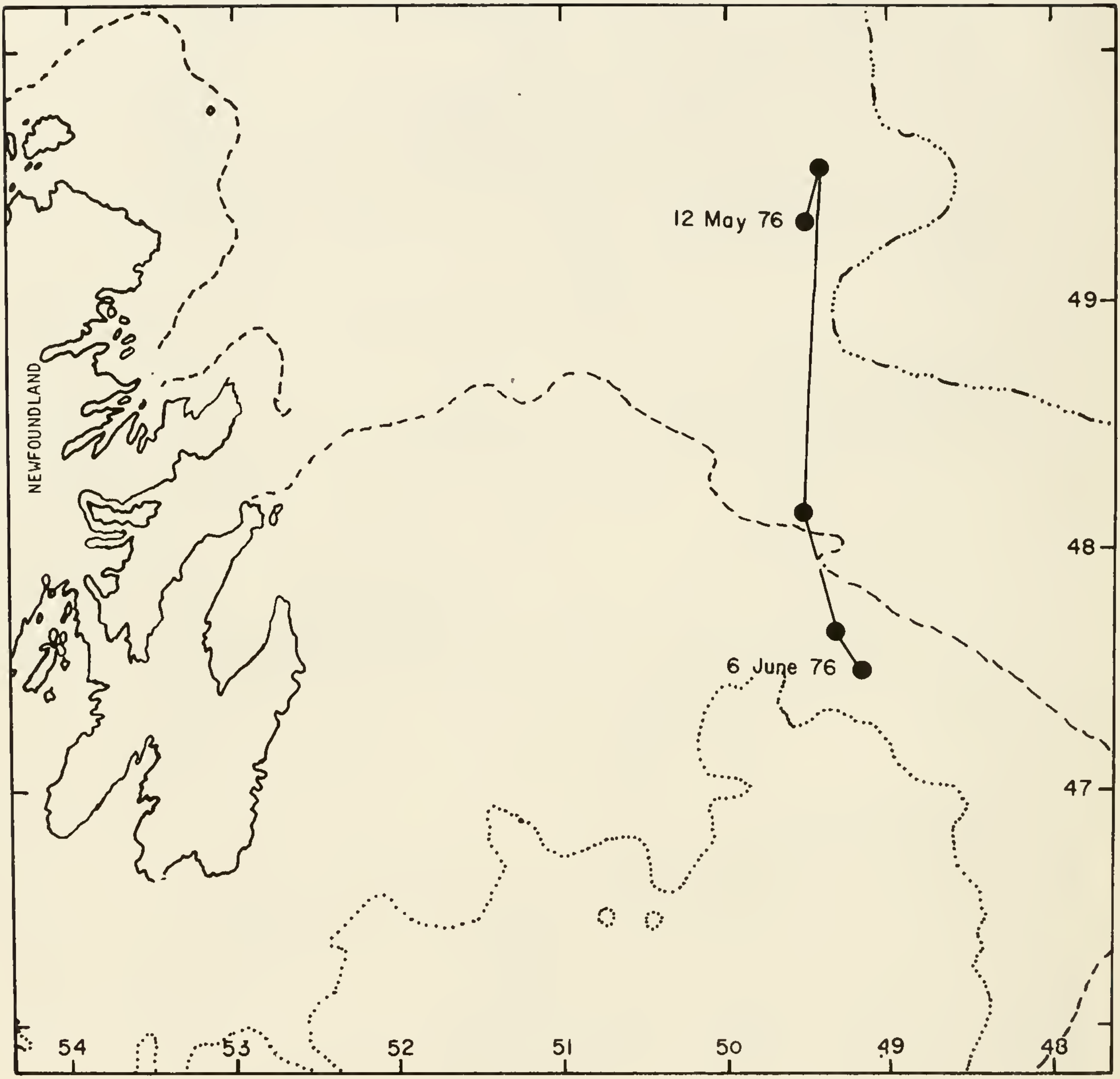


Figure B–2.—Drift Track of a large tabular iceberg near the Grand Banks of Newfoundland.

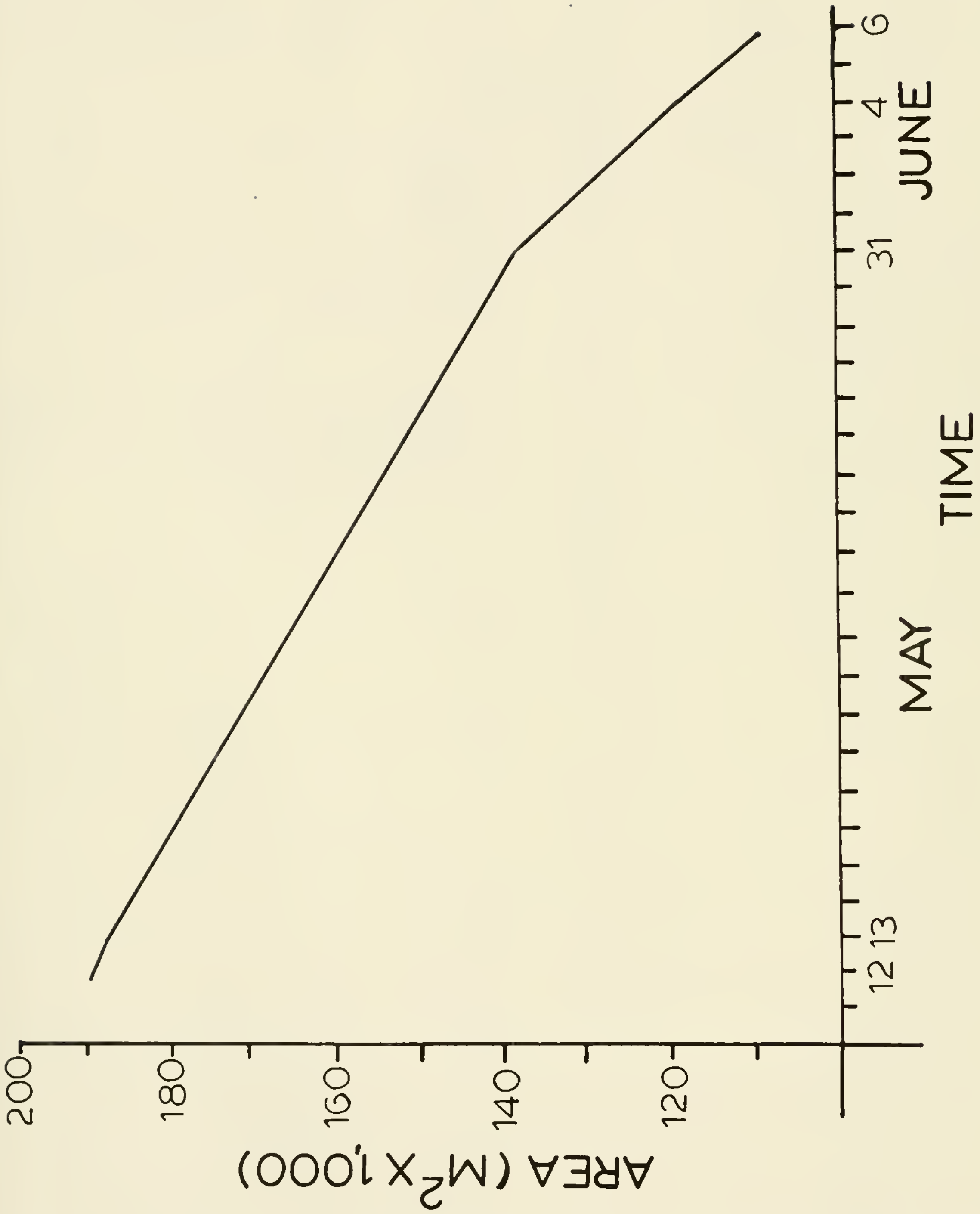


FIGURE B–3.—The reduction of the iceberg's sea level horizontal area as a function of time.

control. There is also an alternation of light and dark bands which while quite subtle are obvious on close examinations of an original photographic print. The banding is not a result of the drainage pattern since it is crossed by drainage channels in numerous locations. The band pairs do not seem to be regularly spaced nor are they perfectly linear or parallel for the width of the iceberg. We feel that such a structure is likely to be the result of flow and that the light and dark bands represent streamlines. The two parallel ridges are possibly the result of shear or flow over an irregularity of the glacial bed.

The iceberg's origin remains unknown. The Ward Hunt ice shelf on northern Ellesmere Island, Petermann Glacier in Hall Basin and Humboldt Glacier in Kane Basin are all capable of producing a thin tabular iceberg. Usually such icebergs fragment and deteriorate before they reach 50°N latitude. The last sighting of a similarly-shaped iceberg on the Grand Banks by the International Ice Patrol was in 1964 (Lenczyk, 1965). Twenty large tabular icebergs, some as long as 600m, were sighted by the Ice Patrol aircraft in late February of 1964 between Hamilton Inlet and Cape Chidley. They appeared as far south as 44°N by early May 1964. These icebergs were thought to have their origin in ice island WH–5 which was observed to block the Kennedy Channel from the Canadian shore to Hans Island in 1963 (Franceschetti, 1964).

A low tabular berg of this size is quite unusual and fortunately rare. It represents a greater than usual hazard for surface vessels due to its lower probability of detection, particularly in a seaway. The iceberg's uniqueness contributed to the attention given it by the International Ice Patrol.

REFERENCES

Lenczyk, R. E., Report of the International Ice Patrol Service in the North Atlantic Ocean (Season of 1964). Coast Guard Blletin No. 50 (1965).

Franceschetti, A. P., U.S. Coast Guard Oceanographic Report No. 5, 1–36 (1964).

APPENDIX C

WEST GREENLAND GLACIER SURVEY

R. C. KOLLMEYER, CAPT, USCG, Ph.D.
U.S. Coast Guard Academy

The statutory mission for the conduct of the International Ice Patrol provides for a study of ice and current conditions affecting the occurrence of icebergs in the North Atlantic Ocean. Commencing in 1914, the Coast Guard undertook a systematic series of oceanographic and ice studies. By 1928, these studies included the glacier origins of icebergs. Expeditions carried out by RADM E. H. SMITH between 1928 and 1935 identified twenty-one glaciers which make major contributions to iceberg occurrence in the North Atlantic Ocean. Average annual production rates for these glaciers were estimated and glacier front advance or retreat were determined qualitatively within the limits of available information.

The present ongoing West Greenland Glacier Survey was established in 1968. The intervening 33 years since SMITH's work left questions about changes and trends in the glaciers. The decades of the 1950's and 60's showed a decline in the mean number of icebergs drifting into the Grand Banks/Ice Patrol area. This was precipitous in comparison to the steady iceberg populations during the proceeding 50 years. Future planning and budgeting for International Ice Patrol, as well as planning for the possibility of greater arctic shipping obviously required a reinspection of the general productivity of the glaciers that produce the icebergs which hazard shipping. Trends during the first half of the 1970's turned out to be the reverse of the 50's and 60's. 1972 became the greatest year ever for icebergs on the Grand Banks and 1974 was the second greatest year on record. 1973, although not record breaking, saw two and one-half times the number of icebergs of a normal year. Conflicting interpretations of these data are obviously possible: advancing glaciers, abnormal meterorological conditions or a catastrophic breakup of the great floating ice tongues of West Greenland are all possibilities. Certainly, any of the above explanations can impact on the costs of operations for the Coast Guard. Glacial advance portends more ice and greater Coast Guard surveillance, and adversely affects the prospects of greater oil and mineral surface transport from the eastern Arctic. Glacial retreat, producing first a calving reduction, next a thinning of the floating ice tongues and then a rapid breakup, initially results in a declining population of icebergs followed by greatly increased numbers and then ultimately few.

In order to provide answers to the questions iterated above, the following objectives of the West Greenland Glacier Survey are being pursued:

1. Survey the West Greenland iceberg producing tidewater glaciers and compare the data thus obtained with earlier records to ascertain the advance of recession of the glaciers, future trends and changes in iceberg production rates.

2. Determine the annual number of icebergs calved from the major West Greenland glaciers and the regularity of production to determine the causes of annual number variation of icebergs found on the Grand Banks.

3. Survey environmental conditions affecting the calving and seaward drift of icebergs. This includes fjord configuration, sill depth and coastal circulation.

4. Provide a present pictorial and data documentation of the outlet glaciers of the last continental ice sheet in the Northern Hemisphere for future historical scientific use.

5. Provide the opportunity for invited glaciologists and polar scientists to participate in the

survey, contributing their knowledge and skills and conducting their own studies of Arctice regions not normally accessible to them.

An indirect benefit of the glacier surveys has been involvement of Coast Guard Academy cadets during the summer. Introduction of these cadets to arctic operations and icebreaking provide a source of interested and initiated Icebreaker officers.

The region of the West Greenland Glacier Survey is shown in Figure C–1. The first study, conducted in 1968, was staged from USCGC EASTWIND. The research group, headed by CAPT R. P. DINSMORE, surveyed the major glaciers from Jacobshavn (69°15′N Lat) to Northwest Bay. Jacobshavn is the southernmost glacier in the entire area of interest. In 1969, CAPT R. C. KOLLMEYER became the principal investigator and, using USCGC SOUTHWIND, surveyed between Upernivik and Kap York. Based on experience gained in 1968, detailed survey procedures, data gathering methods and photographic documentation commenced with this second study. The 1970 survey, conducted from USCGC WESTWIND, visited the glaciers from Kap York to Petermann Glacier in Hall Basin (81°30′N Lat), the northernmost glacier of the survey. Following this, the Coast Guard Academy took responsibility for the project with Captain KOLLMEYER remaining in charge. In 1971, the first in a series of planned revists was carried out, resurveying and photographing those glaciers visited in 1968. Due to ship schedules and mechanical problems, no additional surveys were conducted until the summer of 1976. At the time, USCGC WESTWIND supported a July survey conducting flow measurements of Jacobshavn Glacier, by now identified as the prime producer of icebergs threatening North Atlantic shipping. An automatic time-lapse motion picture camera viewed the terminus of the glacier in order to determine the regularity or irregularity of glacial movement. The camera was retrieved 18 days after its establishment and produced a remarkable record of glacier movement modes never before obtained. The 1968 and 1970 surveys were accompanied by a Coast Guard photomapping flight. High altitude stereo overlapping vertical photographs were obtained along the coastline from Jacobshavn Glacier north to the Humboldt Glacier.

The usual procedure for the survey of a glacier is as follows:

1. Conduct a helicopter flight to survey the region and select sites from which physical measurements of the glacier can be made.

2. After placing one or two survey parties ashore, locate the survey site by using visual landmarks and establish a metallic marker from which all data are referenced.

3. Optically survey the glacier terminus using a theodolite and laser rangefinder. Due to the size of some glaciers, triangulation is necessary from two different survey sites. The survey maps the shape and location of the calving terminus.

4. Measure optically the height of the calving terminus at as many points as possible. Measure floating tabular bergs when present.

5. Make observations concerning recently unglaciated or overrun terrain near the glacier, tidal markings on terminous, calving activity and freshness of the calving surface, iceberg population and fresh ice near the terminus, the presence of upwelled melt water immediately in front of the glacier, streaming zones and noise. Sketch the glacier.

6. Mark the survey site with a rock cairn to make it easily locatable in the future.

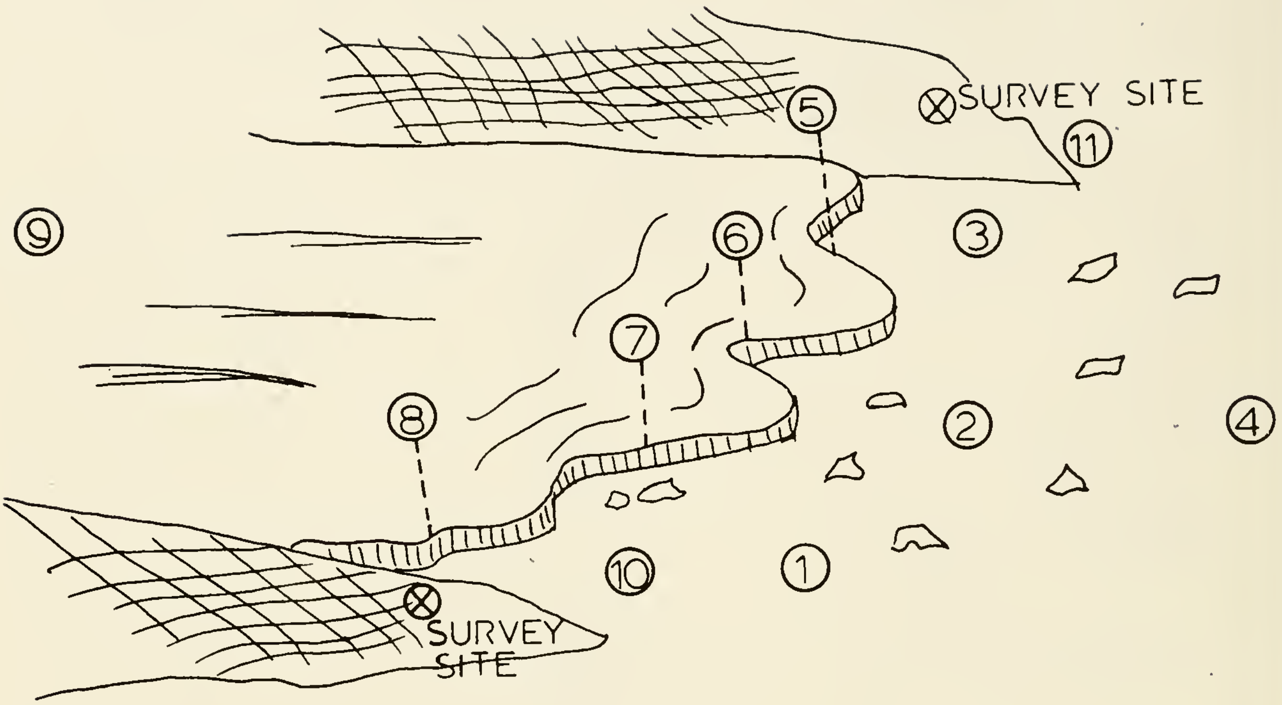
7. Photographically document the glacier from the survey site as well as the site itself and the surrounding terrain.

8. Complete a detailed photographic flight and document the glacier in accordance with the picture sequence shown on Figure C–2. (This is generally accomplished while the field parties are conducting the ground survey.)

9. Conduct oceanographic observations from the Icebreaker, including fjord soundings, sill depth determination and coastal and fjord water properties.

Variations in this procedure are often made depending on the glacier and the situation. Many minor glaciers are only photographed. To add to our knowledge, a number of coastal villages have been visited in order to obtain information on long-term ice trends observed by the residents.

FIGURE C-1.—West Greenland Glacier survey area.



(1) Oblique shots above and seaward of glacier to get detailed pictures of front face at an altitude of about 500 to 800 feet depending on glacier size. Same for photos (2) and (3) or as many as necessary to show the details. Provide for about 1/8 picture overlap.

(4) Panoramic shot, wide angle lens, from about 2500 to 3000 feet altitude to show lateral extent of glacier including edges of land on either side.

(5)(6)(7)(8) Vertical shots from 2550 to 300 feet altitude of entire terminus of glacier with 1/8 to 1/4 overlap. As many shots as required to cover entire glacier terminus.

(9) Seaward photo at about 2500 feet with wide angle lens. Similar to number (4) but shot in opposite direction.

(10)(11) Picture of each survey site which will include a portion of the glacier for orientation.

FIGURE C–2.—Picture sequence used to photographically document the terminus of the glaciers surveyed.

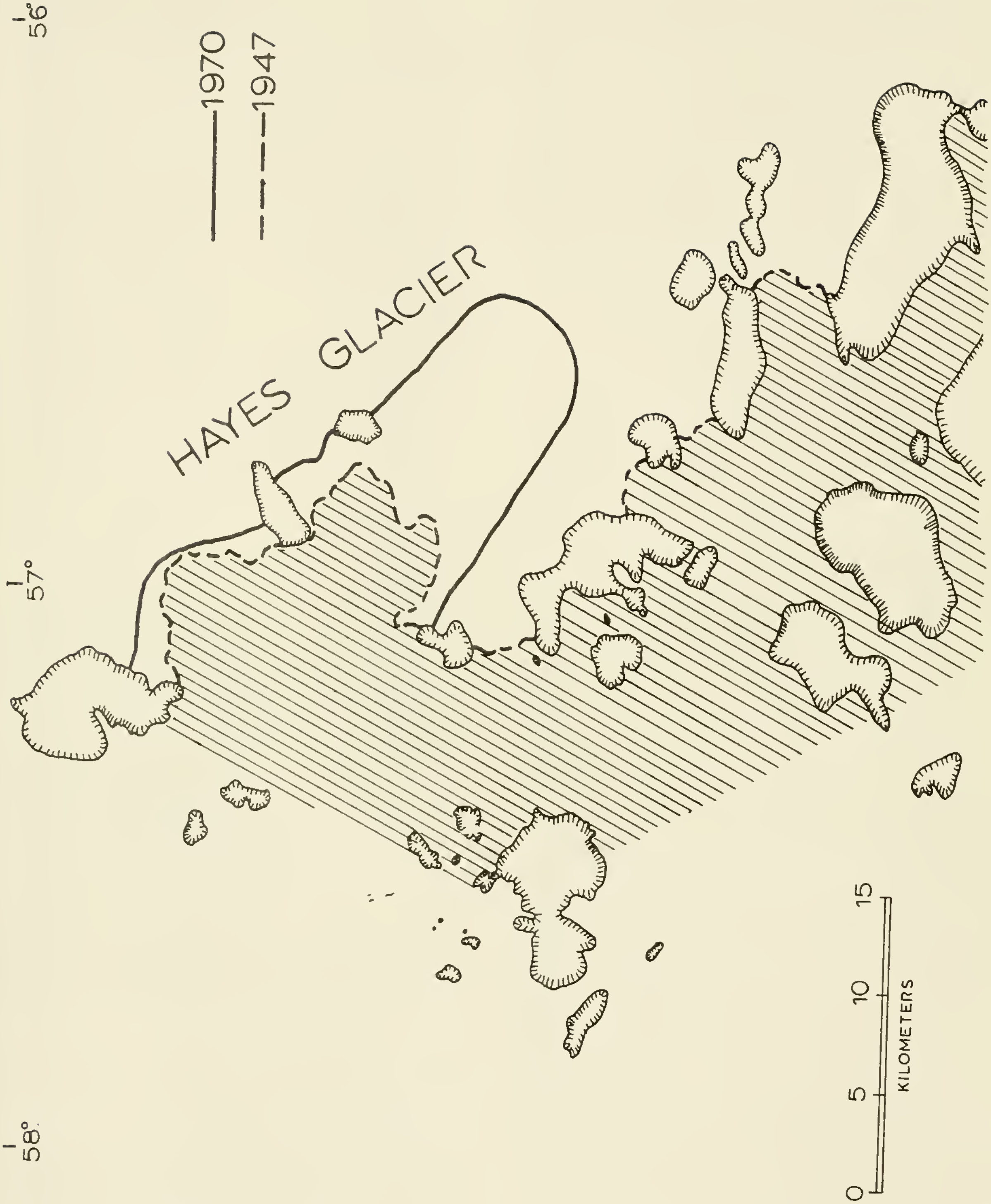


FIGURE C-3.—Terminus of Hayes Glacier as measured in 1947 and 1970. Shaded area denotes open water within fjord.

The following polar scientists have accompanied the Glacier Survey in past years.

1968 Dr. William Carlson, Glaciologist, University of Toledo
Mr. Dennis Trabant, Glaciologist, University of Toledo
Mr. John Mercer, Glaciologist, Ohio State University

1969 Mr. Louis Miller, Glaciologist, University of Alaska
Mr. David Potter, Glaciologist, and original survey team member for Sondrestrom AFB Greenland, 1940. Potter Instruments, N.J.

1970 Dr. Kenneth Allen, Zoologist, University of Maine
Dr. John Dearborn, Zoologist, University of Maine

1971 Dr. Terrence Hughes, Glaciologist, Ohio State
Mr. Frank Kuesel, Lichenologist, Ohio State

1976 Mr. R. Quincy Robe, Oceanographer, IIP research, CG R&D Center
Dr. Terrence Hughes, Glaciologist, University of Maine
Dr. Robert Thomas, Glaciologist, University of Maine
Mr. Craige Lingle, Glaciologist, University of Maine

To date, the West Greenland Glacier Survey has extensively surveyed from the ground 26 major iceberg producing glaciers. One additional glacier was visited and surveyed with sextant measurements. A total of 59 outlet glaciers have been photo-documented with color film from low flying helicopters and the entire West Greenland coastal region photographed twice by aircraft from 8000 feet. Six glaciers have been revisited after a three year interval. The glacier names and the years visited are listed in Table C–1.

In addition to the geographic documentation cited above, the significant accomplishments of this survey are:

1. Through comparisons of present surveys with historical data, a general retreat of the tidewater glaciers of West Greenland is documented. Some glaciers have retreated as much as 13 kilometers in 22 years as shown by the changes in Hayes Glacier, Figure C–3, to cite one example.

TABLE C–1—GLACIERS VISITED

	Glacier	*Photographed*	*Surveyed*
1968	Umiamako		X
	Rinks		X
	Great Karajak		X
	Little Karajak—sextant angles/observation		—
	Eqip		X
	Avangnarelleq (Torssukatak)		X
	Kujatdleq		X
	Jacobshavn		X
1969	Gade	X	X
	Helland	X	
	Wulff	X	
	Yngvar Nielson	X	
	Mohn	X	
	Unnamed!	X	
	Morell	X	
	Docker Smith	X	X
	Rinks	X	
	Pearys	X	X
	Kong Oscar	X	X
	Nansen	X	X
	Dietrichson	X	X
	Sverdrup	X	
	Steenstrup	X	X
	Kjears	X	
	Hayes	X	X
	Giesecke	X	X
	Upernivik	X	X
	Cornell	X	
	Ussings	X	
	Nordenskiolds	X	
1970	Humboldt	X	X
	Petermann	X	X
	Bissels	X	
	Morris Jesup	X	X
	Clements Markham	X	
	Diebitsch	X	
	Meehan	X	
	Verhoeff	X	
	Sun	X	
	Bowdoin	X	X
	Tracy	X	X
1970	Heilprin	X	X
	Farquaar	X	
	Academy (Leidy)	X	X
	Petowik (Pitugfix)	X	X
	Sermerssuaq (Moltke)	X	X
	Knud Rassmussan	X	

Glacier	Photographed	Surveyed
Agpat	X	
Hart	X	
Sharp	X	
Melville	X	
Savage	X	
Berlingske	X	
Hurlbut	X	
Chamberlin	X	
Brother Johns	X	
Dodge	X	
San Martin	X	
Hubbard	X	
Marre	X	
Unnamed!	X	
1971 (Glaciers from 1968 expedition resurveyed)		
Jacobshavn	X	X
Rinks	X	X
Uniamako	X	X
Great Karajak	X	X
Avangnarelleq (Torssukatak)	X	X
Kujatdleq	X	X

2. Redefinition of those glaciers considered major iceberg producers by RADM E. H. SMITH. Several that he felt contributed to the ice patrol problem are now grounded and not producing icebergs. Others, never visited by SMITH, have been added to the major producer list.

3. Determination of floating glacier elevations with over 120 measurements of height made. A significant contribution since floating ice terminus elevation data are virtually nonexistent in the literature.

4. Tidal measurements and a number of horizontal movement vectors were determined for Jacobshavn Glacier. On two different visits, velocities of up to 21 meters per day were obtained by optical observations. This is the fastest movement ever detected in a steady flowing glacier.

5. Time lapse motion pictures of Jacobshavn Glacier obtained over 18 days. These pictures disclose the glacier's flow movement to be surprisingly, steady, river like in manner.

6. Iceberg volume production estimates have been computed for Jacobshavn Glacier showing an annual production of 27.6 cubic kilometers of ice. This is about 10% of the total iceberg volume produced by all of West Greenland.

7. Homboldt Glacier, all 60 nautical miles of its terminus, was surveyed from the ground using both land pin points and NAVSAT navigation for seaward measurements. This survey of the terminus location of the largest glacier in the northern hemisphere had never been accomplished before. One interesting finding is that with all the prodigeous potential for iceberg production, successive year aerial surveys showed the same iceberg sitting in place, grounded and obviously not part of the major supply of icebergs to the Grand Banks region. The Explorers Club of New York sent Explorer Club flag number 193 which was flown over the survey sites during this first time survey of the Humboldt (1970).

8. Petermann Glacier, 81°30′N, originally observed during the ill-fated Hall-Polaris expedition of 1871–73, was found in 1970 to be a badly wasted, low profile floating ice tongue with no iceberg production. It was surveyed and described in 1872 as "a confused accumulation of bergs, crowded closely together, leaving such spaces only as were due to irregularities of form". Petermann fjord was full of icebergs then and those icebergs could have come only from Petermann Glacier. Hall's ship, the Polaris, wintered over there while moored to a giant iceberg. In 1970, there were no icebergs nor a possible source of icebergs within 100 miles of Petermann fjord.

9. The development of "in-house" expertise in the field of glaciology by Captain KOLLMEYER through text book and journal studies over the last eight years and on-site glacial work during the survey expeditions. This includes the development of several techniques of marking glaciers to allow optical measurements of movement to be performed both from the surface and through the use of aerial photography. This expertise within the Coast Guard has been recently expanded because of the involvement of LCDR Howard B. GEHRING, USCG and R. Quincy ROBE, IIP Research, Coast Guard R&D Center, in the 1976 survey expedition.

With the data already obtained by the West Greenland Glacier Survey, objectives 3 and 4 above have been accomplished. Objective 5 should be a continuing program for visiting scientists as long as the survey is pursued and space on the Icebreaker is available. Objective 1 has been accomplished with the exception of

definition of trends. Resurvey of certain glaciers could better establish these trends. Objective 2, completed for Jacobshavn Glacier, can also be accomplished for the other major producers by resurvey where the time spent at each glacier is basically devoted to measurements of glacier movement. Thus, future plans for the West Greenland Glacier Survey call for continuing the resurvey program of the major iceberg producing glaciers to obtain verification data and to detect the continuance of the recession trends. Site reoccupation would include both tidal flexure measurements and short-term flow velocity determinations. These data will allow iceberg production calculations. A total of three more survey expeditions, visiting only the most productive glaciers, would be required. In addition, a program of ERTS Satellite monitoring of the glaciers will be commenced. As satellite technology improves, all iceberg production and glacier retreat monitoring will be accomplished remotely and at comparatively little expense.

The quantity of photographs and recorded data obtained since 1968 is large. The Glacier Survey has very thorough documentation of the glaciers of West Greenland. This information would be quite useful as a reference resource to glaciologists, oceanographers, climatologists and geographers. Historically, these data are an important benchmark in the geophysical studies of the earth. I hope they will be published and made available in the most complete and definitive form possible, with a complete narrative, data measurements, calculations and color photographs, with the photographs being of prime importance.

APPENDIX D

OPERATIONAL USE OF FREE-DRIFTING, SATELLITE-TRACKED BUOYS

C. R. WEIR, LT, USCG
U.S. Coast Guard Oceanographic Unit

The 1976 Ice Patrol season initiated the Coast Guard's use of the Buoy Transmitting Terminal (BTT) buoy system. This system is capable of drifting with the ocean currents and transmitting information via satellite. The information is then relayed to ground stations where environmental data and buoy position are determined. A BTT buoy, called the Conshelf Drifter, is shown in figure D–1. This buoy is manufactured by Polar Research Labs of Santa Barbara, California. The buoy used in 1976 was manufactured by NOVA University, Fort Lauderdale, Florida and was very similar in shape and design. A window shade drogue 13 meters long and 2 meters wide was used to increase water drag. A full description of this type of drogue is contained in Vachon (1975).

The position fixing capability and the transmission of environmental data are accomplished through the use of the Nimbus–6 Satellite Random Access Memory System (RAMS). The technical specifications are given by Sissala (1975). Basically, the BTT buoy broadcasts a frequency stabilized UHF signal for 1 second every minute regardless of whether or not the buoy is within sight of the satellite. Contained within this signal is a platform identification number and four eight-digit words. During a satellite pass the spacecraft receives this information and accurately determines the frequency at which it was received. The doppler shift information is used to determine the buoy's position.

The buoy used in 1976, platform I.D. 0177, was deployed on 4 April in position 46°59.2′N, 47°15.1′W along standard section A–2. Excellent data were received through 13 April. During this time 5 to 11 positions were obtained every day. On 11 April a storm moved the buoy westward and up onto the Grand Banks. The depth in this area decreases to 100 meters or less and may have interfered with the drogue. After 13 April the buoy experienced an intermittent electronic failure and positions were obtained only on the days shown in figures D–2 and D–3. These figures show the BTT movement relative to general ocean currents. The last transmission from the buoy was on 15 September 1976. A detailed analysis of the data that were obtained from this system will be the subject of a separate report.

The data from the buoy yielded three important results. The first was the buoy's apparent response to wind currents. On April 4th, 5th and 6th the buoy drifted northwest and not southwest as indicated by the dynamic topography. During this same period the wind was from the southeast at speeds up to 35 knots. The second interim finding was that the buoy's drift direction during periods when the wind was less than 20 knots closely followed the dynamic topography. The third result was that during the period of moderate winds the buoy moved along the edge of the Labrador Current at an average speed of about 30 cm/sec. The dynamic topography of a survey taken just previous to this experiment gives an average speed of about 25 cm/sec.

These three results have a major impact on iceberg drift and they further confirm our previously held beliefs; that is, wind generated currents must be considered when determining iceberg drift, that dynamic topography is quite accurate in determining the baroclinic component of the current direction, and that dynamic topography produces a current speed that is too conservative.

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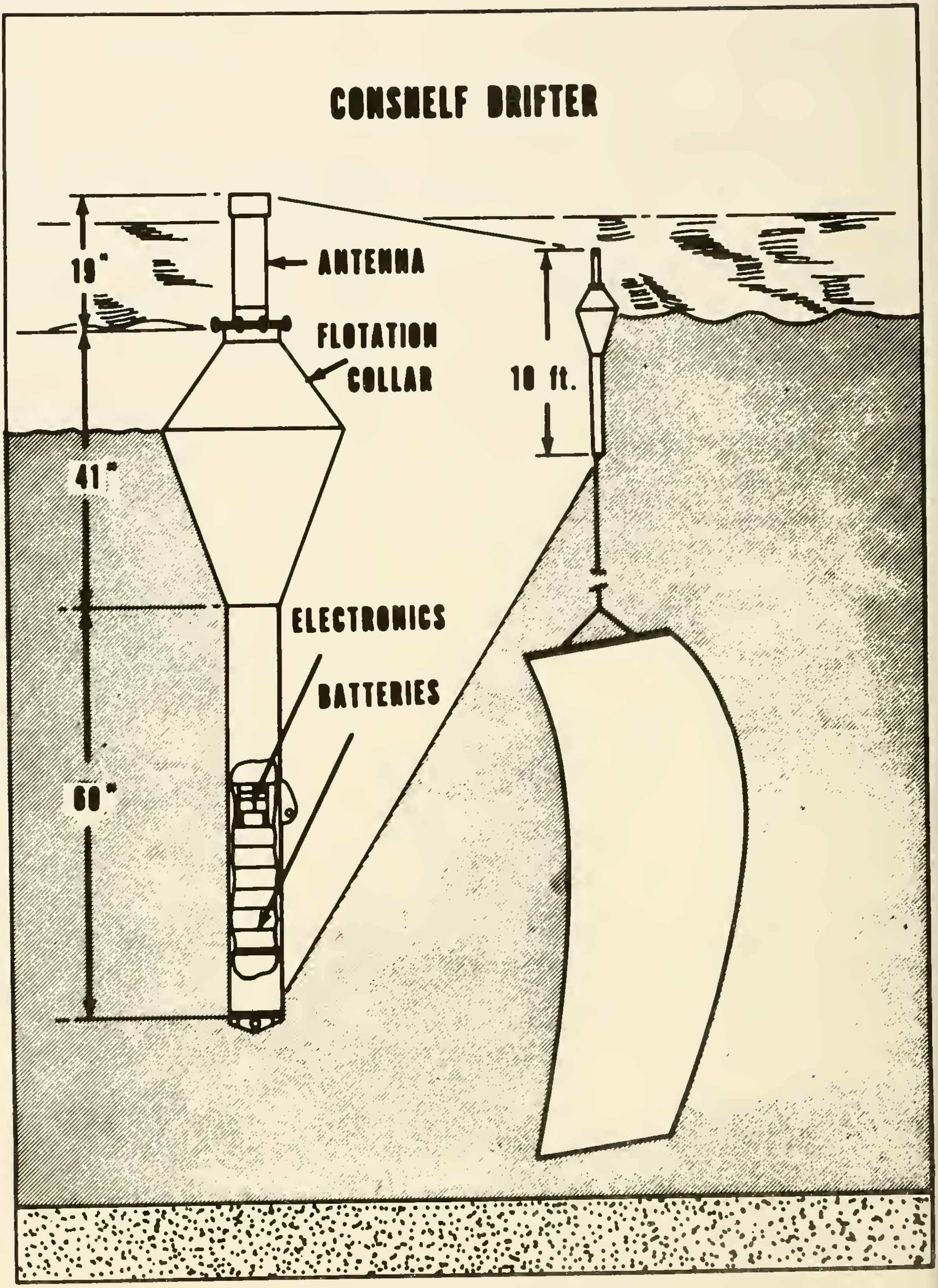

Figure D-1.—BTT buoy design.

MONTHLY NORMAL DYNAMIC TOPOGRAPHIC FOR APRIL

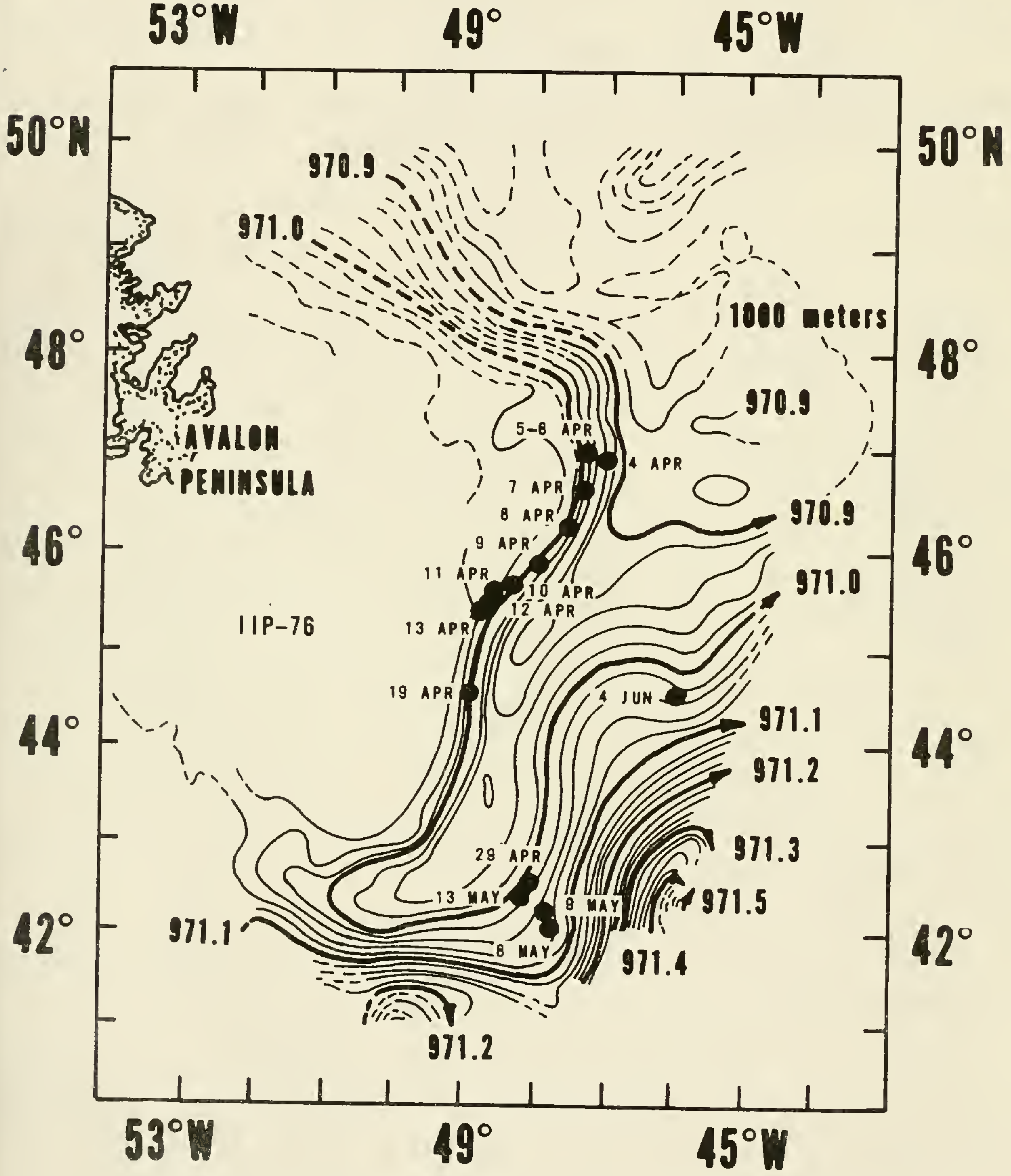

Figure D–2.—Drift of BTT buoy within the IIP area (I.D. 0177).

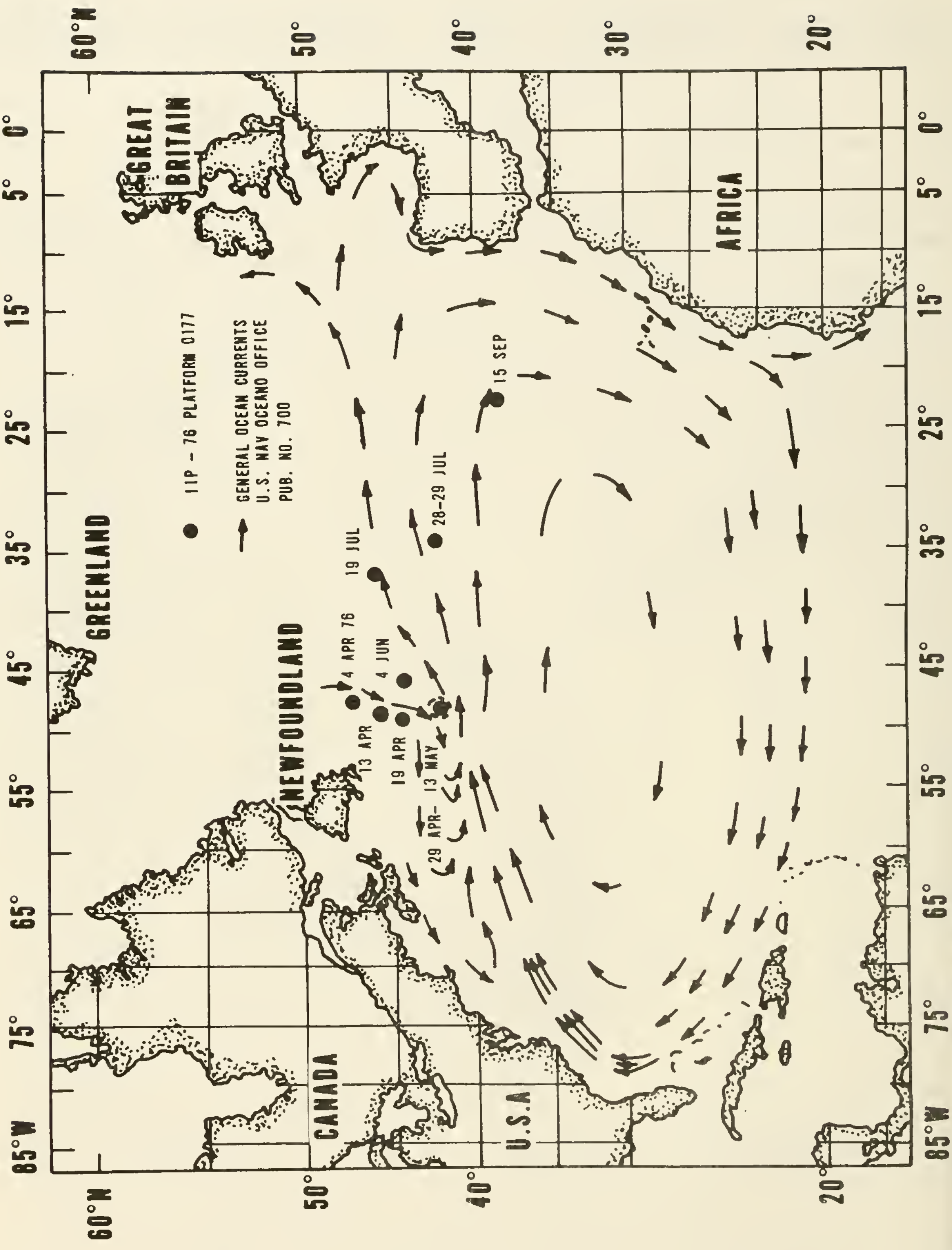

FIGURE D-3.—Drift of BTT buoy from 4 April to 15 September 1977 (I.D. 0177).

APPENDIX E

OBSERVATIONS OF SEA SURFACE TEMPERATURES IN THE VICINITY OF THE GRAND BANKS

H. G. KETCHEN, LT, USCG
Staff Oceanographer
International Ice Patrol

The International Ice Patrol has an operational need for reliable, accurate sea surface temperature (SST) data in the vicinity of the Grand Banks to be used in the prediction of iceberg deterioration rates and definition of certain ocean current regimes. The Grand Banks offers one of the most dynamically active ocean areas in the world with the cold, narrow Labrador Current meeting the warm North Atlantic Current. This situation, complicated by the fact that both currents constantly vary in magnitude and position, account for relatively rapid changes in oceanographic features, including SST. To maintain a useful plot of SST data, frequent updates are needed. Ice Patrol presently receives SST reports from merchant vessels transiting the area, hourly from the Ice Patrol Oceanographic Research Vessel (USCGC EVERGREEN) when in the vicinity of the Grand Banks, from airborne radiation thermometer (ART) surveys conducted on routine ice reconnaissance flights and from satellite infrared imagery.

Due to the remoteness of the Grand Banks area, ship reports are infrequent. Even with U.S. Coast Guard Oceanographic Cutter EVERGREEN reporting hourly SST's, vessels alone cannot provide the coverage and density of samples necessary to develop the SST contours needed by Ice Patrol.

In the latter part of the 1974 Ice Season, Ice Patrol began its first operational use of the ART. Although IIP had experimented with infrared recording devices for a number of years (OSMER, 1974), this marked the first time the ART had been used operationally on the Grand Banks. The first recorded use of an infrared device for measuring water temperatures from an aircraft was by Woods Hole Oceanographic Institute in surveying the Gulf Stream (STOMMEL et al, 1953). They found that an airborne infrared detector was capable of providing a chart of surface thermal gradients over a much greater area than could be covered by surface vessels, and in a much shorter time. Continuing research using the Stommel-Parsons instrument, they developed a series of thermal gradient charts that defined the fine structure of the Gulf Stream front (VON ARX et al, 1955). With the potential value of the instrument determined, its use became more widespread.

Using a more sensitive instrument manufactured by the Barnes Engineering Company, Richardson and Wilkens (1958) reported the existence of certain errors in sea surface radiation measurements from aircraft. These appeared to result primarily from the reflection of solar radiation from the sea surface and the atmospheric conditions at the time of recording. The atmospheric errors were due to radiation absorption by atmospheric water vapor in the 5 to 7 micrometer band, and by carbon dioxide in the 14 to 16 micrometer band; thus the 8 to 13 micrometer window was found to be most useful for infrared remote sensing (KETCHEN et al, 1977).

International Ice Patrol has been using the Barnes PRT–5 for ART surveys, operating with a 9.5 to 11.5 micrometer window while flying at altitudes of 1000 feet or lower. Even with this window, any appreciable amount of water vapor in the air column between the aircraft and the water surface (including light fog, thin cloud cover and water spray from strong surface

winds) has been found to have a significant effect on the accuracy of the ART record. This fact has prohibited the effective use of the ART during roughly 40% of the reconnaissance missions flown by the Ice Patrol.

The Center for Cold Ocean Resources Engineering (C-CORE) at Memorial University of Newfoundland in St. John's has recently tested two techniques for applying correction factors to account for atmospheric attenuation. Although not presently using either of these techniques, IIP is considering their use for improving the absolute accuracy of the ART surveys. In these methods, an emissivity value of almost unity is assumed for water; thus, no emissivity correction is contained in either procedure.

Pickett Method

This technique uses an empirically derived correction equation that uses multiple regression (EFROYMSON, 1964). Environmental variables considered in the derivation were altitude, altitude squared, square root of altitude, air temperature squared, square root of air temperature, the difference between air temperature, and ship bucket temperature (PICKETT, 1966). Pickett used these variables because they could be easily and accurately measured. He did not take into consideration humidity effects. Using correlation coefficients between the ART error and the environmental variables, Pickett determined that altitude and air temperature were the two most important variables. From his results the following empirical environmental correction equation was determined:

$$C = 1.54 + 0.00046A - 0.043T,$$

where, C = environmental correction to be added to the ART value (°C)

A = altitude in feet, and

T = air temperature at 1,000 feet (°C).

Pickett devised a chart for quick determination of the correction for the radiation temperature that compares that altitude (feet) versus air temperature at flight level.

Atmospheric Environment Service Method

This method evolved from a computer procedure that was used to correct Richards' (1966) data (SHAW, 1966). Shaw and Irbe (1972) and Irbe (1972) have described a graphical method that required knowledge of the vertical distribution of temperature and humidity in the vicinity of the aircraft. They felt that corrections for the air column above 2,000 feet were unnecessary, and that the correction using the graphical means was comparable to the measurement error of the recording instrument (±0.5C°) specifications. They found that an overcast cloud layer increased the ART reading by 0.5C° above the values for clear sky. Irbe (1969) found that the atmospheric correction was of utmost importance for reducing data if unusual surface water temperature patterns were to be discerned and Shaw and Irbe (1972) felt that the instrument could be extremely useful in monitoring surface water temperatures near freezing.

The correction technique involves the determination of instrument drift over the flight period using inflight calibration; the plotting of an environmental correction graph which is a plot of the ART temperature with drift corrections versus the measured surface water temperature; and the application of a correction factor for errors due to the water vapour mass under the aircraft. The water vapour data were recorded from independent information available from the nearest upper air meteorological station. Irbe (1972) contains the required graphs for carrying out the corrections. This technique replaced the computer method of Shaw (1966), and has proven satisfactory for the AES program.

Of the two correction methods, the AES correction is preferred because it attempts to account for changes in temperature and humidity of the air column under the aircraft. This correction is also sensitive to changes from clear to overcast skies. The Pickett method is very insensitive to altitude changes and outside air temperature and makes no allowances for humidity. The Pickett method was normally 2°C for most of the Ice Patrol Grand Banks surveys in 1976, regardless of atmospheric conditions.

To implement the AES method, accurate outside air temperature and humidity at altitude should be collected at the same time as ART information. This requires an accurate outside air temperature sensor and an airborne hygrometer. Accurate navigational information is available from Ice Patrol aircraft's inertial navigation system, as are altitude readings. Cloud cover could be monitored by the ice observer during the flight.

Surface radiation measurements are also available from satellite sensors. Unfortunately, the imagery provided from satellites presents only varying shades of gray with the warmer waters showing up as dark areas and cold as light gray to white. No absolute values of temperature are assigned to these shades. ART and ship SST data can be used to calibrate the imagery. Temperature contours can then be drawn over the entire area covered by the usable portions of the image (i.e., those not obscured by cloud or fog cover). The obvious advantage of this system is its ability to provide synoptic coverage over a wide area.

Figure E–1 is a satellite IR image of the Northwest Atlantic Ocean oriented with North toward the upper left corner. Point (7) marks position 46°05′N, 45°25′W. Scattered cloud cover can be seen in the lower right half of the photo and over the Grand Banks to the north. Some of the more pronounced temperature gradients have been marked on the image. Figure E–2 is an interpretation of this imagery, calibrated from SST reports received on that date. Figure E–3 was developed totally from ship SST reports received between 3 and 9 May, 1976. ART contours from surveys conducted on 30 April, 1, 5 and 6 May are depicted in Figure E–4. Although there are certainly similarities between all three contours (Figures E–2, E–3 and E–4), some differences are quite obvious. These differences are due to the lack of synopticity and the need to perform interpretative contouring between data points or lines in both figures E–3 and E–4. The satellite imagery provide a much better definition of the surface temperature gradients.

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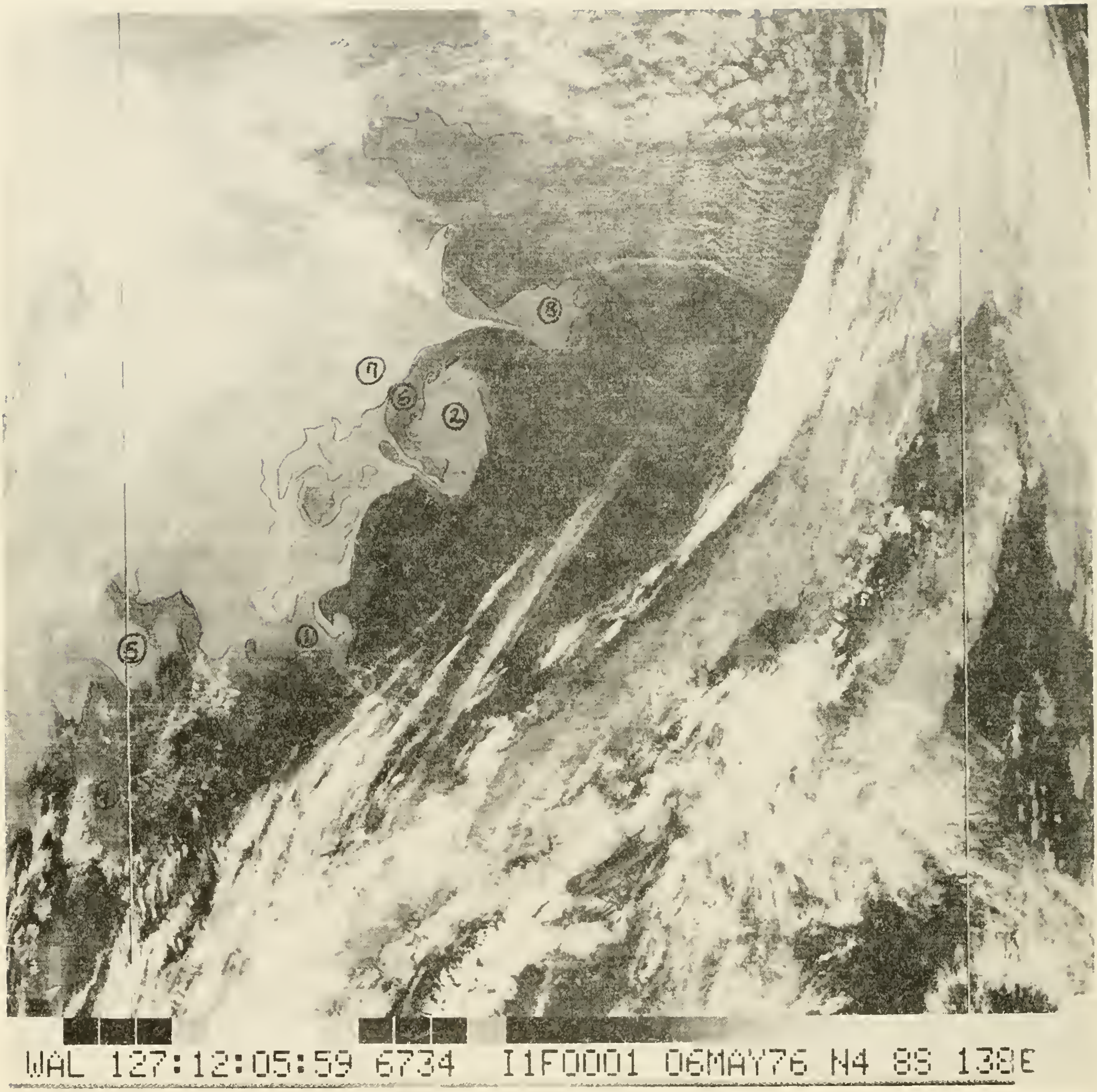

FIGURE E-1.—Thermal Infrared Imagery recorded by a NOAA satellite, May 6, 1976.

FIGURE E-2.—Interpretation of satellite infrared imagery, May 6, 1976 (°C).

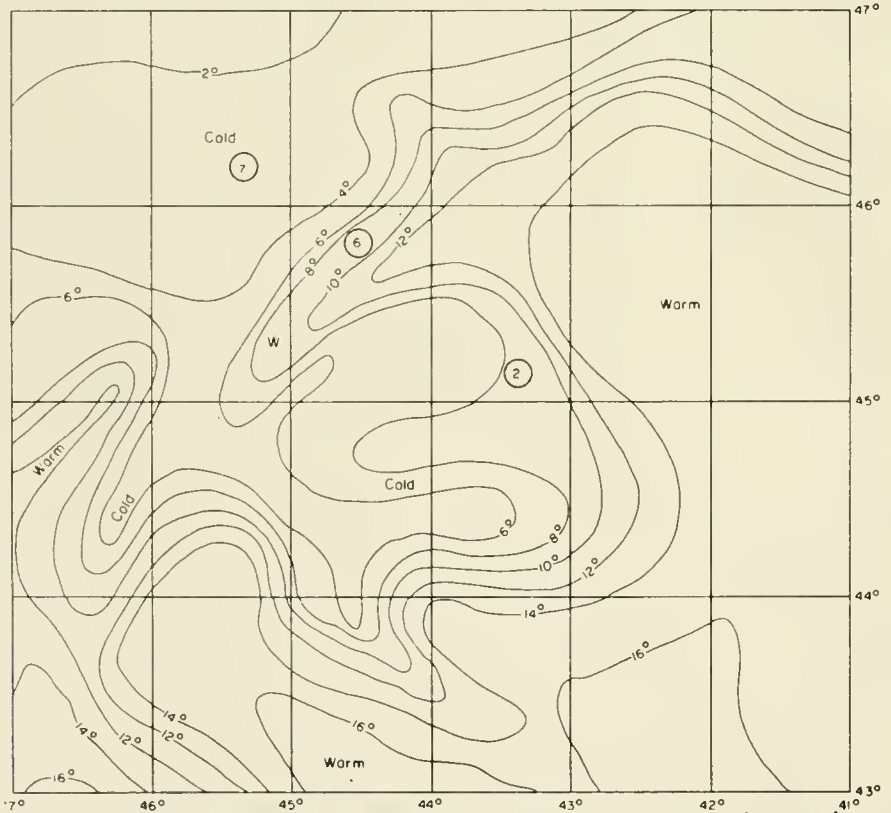

FIGURE E-3.—Sea Surface Temperature Contours developed from ship observations between 3 and 9 May 1976 (°C).

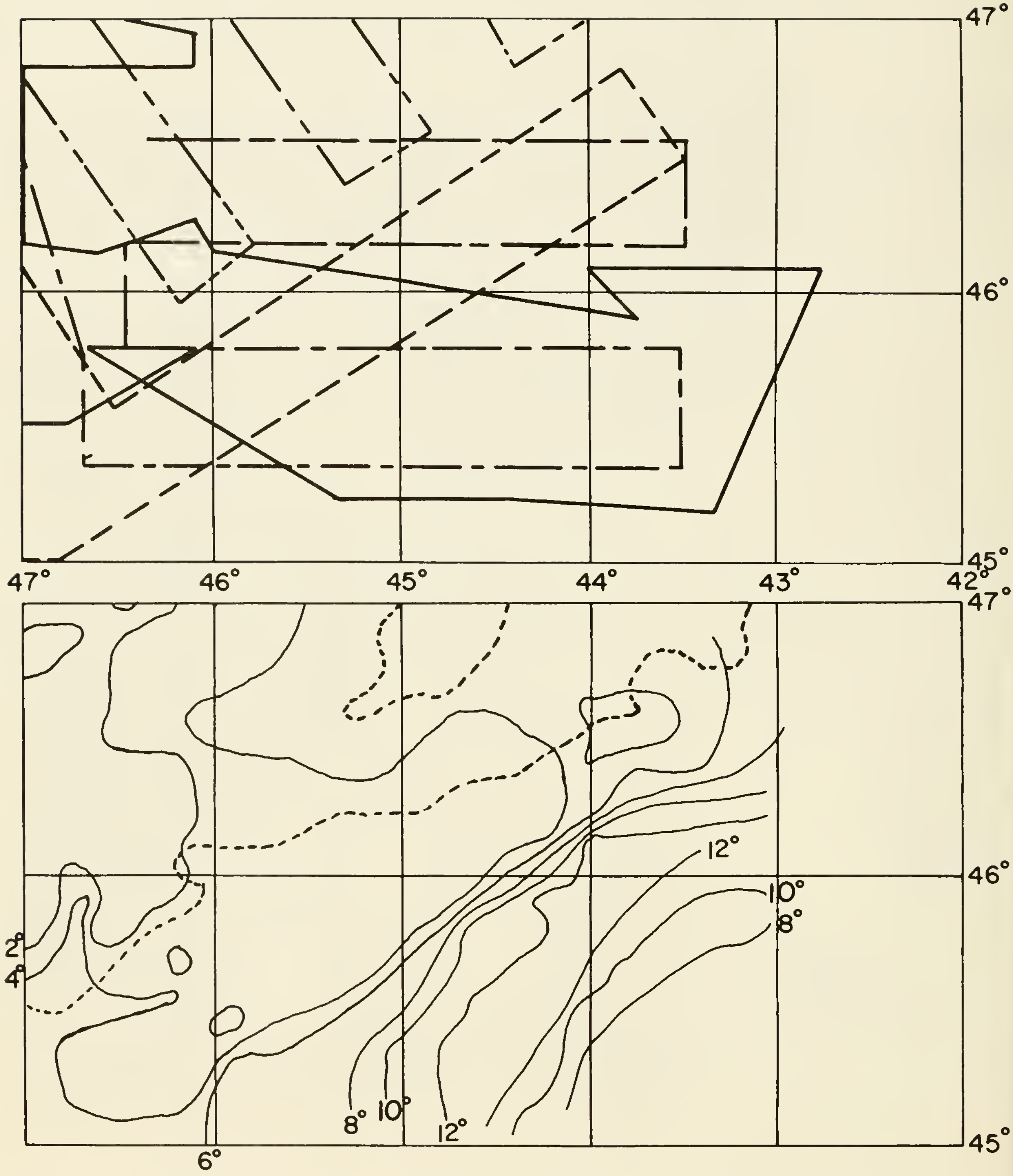

FIGURE E–4.—ART contours of sea surface temperatures as observed during surveys on 30 April and 1, 5 and 6 May, 1976 (°C). Surveys did not cover entire area shown in Figures E–2 and E–3. The top figure shows flight tracks flown during the surveys.

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BULLETIN NO. 63

Report of the International Ice Patrol Service in the North Atlantic Ocean

SEASON OF 1977

CG-188-32

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

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Bulletin No. 63

REPORT OF THE INTERNATIONAL ICE PATROL SERVICES IN THE NORTH ATLANTIC OCEAN

Season of 1977

CG-188-32

FOREWORD

Forwarded herewith is Bulletin No. 63 of the International Ice Patrol describing the Patrol's services, and ice observations and conditions during the 1977 season.

C. C. HOBDY, Jr.
Acting Chief, Office of Operations

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TABLE OF CONTENTS

PREFACE

This is the 63rd in a series of annual reports on the International Ice Patrol Service in the North Atlantic Ocean. It contains information on Ice Patrol organization, communications and operations, and on ice and environmental conditions and their relationships in 1977.

The authors of this report, Lieutenants K. N. KNUTSON and T. J. NEILL, USCG, acknowledge applicable ice, weather and oceanographic data provided by the Canadian Department of the Environment, U.S. National Weather Service, U.S. Naval Weather Service and U.S. Coast Guard Oceanographic Unit. Recognition is given to Chief Marine Science Technician N. O. TIBAYAN, Marine Science Technician First Class C. W. JENNINGS, Marine Science Technician Third Class J. D. STEELMAN and Yeoman Second Class T. L. GEST, all USCG, for their assistance in the preparation of this manuscript and illustrations for this report.

The U.S. National Aeronautical and Space Administration contribution to the continuing effort to devise an all-weather method of detecting and identifying icebergs is gratefully acknowledged.

The continued cooperation and generosity by Canadian Coast Guard Radio Station St. John's/VON is worthy of particular note and gratitude.

INTERNATIONAL ICE PATROL, 1977

The 1977 International Ice Patrol Service in the North Atlantic Ocean was conducted by the United States Coast Guard under the provisions of Title 46, United States Code, Sections 738, 738a through 738d, and the International Convention for the Safety of Life at Sea, 1960, Regulations 5 through 8. The International Ice Patrol is a service for observing and disseminating information on ice conditions in the Grand Banks Region of the Northwest Atlantic Ocean. During the ice season, the southeastern, southern and southwestern limits of the regions of icebergs in the vicinity of the Grand Banks of Newfoundland are guarded for the purpose of informing passing ships of the extent of this dangerous region. The International Ice Patrol also studies ice conditions in general with emphasis on the formation, drift and deterioration of icebergs, and assists ships and personnel requiring aid within the limits of operation of the Ice Patrol forces.

The International Ice Patrol is directed from the Ice Patrol Office located at the U.S. Coast Guard Base, Governors Island, New York. The Office gathers ice and environmental data from a variety of sources, maintains an ice plot, forecasts ice conditions, prepares the twice-daily Ice Bulletin, replies to requests for special ice information, and executes operational control of the Aerial Ice Reconnaissance Detachment, the Ice Patrol oceanographic cutter, and the Surface Patrol cutter when assigned.

Vice Admiral William F. REA III, U.S. Coast Guard, was Commander, International Ice Patrol. Commander Albert D. SUPER, U.S. Coast Guard, was directly responsible for the management of the Patrol.

Preseason Ice Patrol flights were made in January and late February-early March 1977. The Aerial Ice Reconnaissance Detachment was deployed to St. John's, Newfoundland, on 15 March 1977. The Detachment returned to the United States on 22 June 1977, after completion of a Post Season flight on 21 June 1977.

The 1977 Ice Season officially commenced at 0000 GMT, 13 March 1977, when the first Ice Bulletin was broadcast by International Ice Patrol Radio Station Boston/NIK; U.S. Navy LCMP Broadcast Radio Stations Norfolk/NAM; Canadian Maritime Command Radio Station Mill Cove/CFH; and Canadian Coast Guard Radio Station St. John's/VON. Ice Patrol Radio Station Boston broadcast an ice radio facsimile chart once a day.

The USCGC EVERGREEN, commanded by Lieutenant Commander Joseph H. DISCENZA, USCG, conducted oceanographic cruises for the Ice Patrol from 1 April to 1 May and 23 May to 28 June 1977.

During the 1977 season, an estimated 22 icebergs drifted south of 48°N.

AERIAL ICE RECONNAISSANCE

During the period 1 September 1976 to 31 August 1977, a total of 72 ice observation flights were flown; 13 preseason, 58 seasonal, and 1 post season. The objective of the preseason survey was to study the iceberg distribution patterns in the Labrador Sea and to evaluate the iceberg potential of the developing ice season. The season flight objectives were to locate the southwestern, southern, and southeastern limits of icebergs, to evaluate the short-term iceberg potential of the waters immediately north of the Grand Banks, and occasionally to determine the iceberg distributions along the Labrador coast. One post season flight was made to conduct a final census of the icebergs south of 50°N.

The flight statistics shown in Table 1 do not include flight time required to make the passages between U.S. Coast Guard Air Stations Elizabeth City, North Carolina and St. Petersburg, Florida and the Ice Patrol operating airfield at St. John's, Newfoundland for crew relief or aircraft maintenance.

Aerial ice reconnaissance was accomplished by U.S. Coast Guard HC–130B (Lockheed Hercules) four-engine aircraft from Coast Guard Air Stations at Elizabeth City, North Carolina and St. Petersburg, Florida. During the ice season, the aircraft operated out of Torbay Airport, St. John's, Newfoundland, Canada.

On 15 March, the Ice Reconnaissance Detachment deployed to St. John's. This location continues to be the most operationally effective and efficient location for staging Grand Banks reconnaissance. The Detachment remained at St. John's through the season, returning to the United States on 22 June upon completion of the single post season reconnaissance.

TABLE 1—Aerial Ice Reconnaissance Statistics

1 September 1976 to 31 August 1977

Month	*Number of Flights*		*Flight Hours*	
	Visual	*SLAR*	*Visual*	*SLAR*
PRESEASON				
September-December	1*		13.9*	
January	4		20.1	
February	5		31.5	
March	3		18.7	
Preseason Total	13		84.2	
IN SEASON				
March	8	0	37.1	0.0
April	17	0	91.4	0.0
May	19	3	99.3	14.2
June	4	7	16.8	33.9
In-Season Total	48	10	244.6	48.1
POST SEASON				
June	1		6.0	
July-August	0		0.0	
Post Season Total	1		6.0	
Season Totals	62	10	334.8	48.1
	72		382.9	

* USCG Ice Observer participation in a USN ice reconnaissance flight on 10 and 11 November 1976.

COMMUNICATIONS

Ice Patrol communications included ice reports, environmental conditions, Ice Bulletins, special ice advisories, a daily Facsimile Chart, and the administrative and operational traffic necessary to the conduct of the Patrol. The Ice Bulletin was transmitted by teletype from the Ice Patrol office in New York twice each day to over 30 addressees, including those radio stations which broadcast the Bulletin. These stations were the U.S. Coast Guard Communications Station Boston/NIK/NMF, U.S. Naval Radio Station Norfolk/NAM, U.S. Naval Radio Station Londonderry/NST, U.S. Naval Radio Station Thurso/GXH, U.S. Naval Radio Station Keflavik/NRK, Canadian Coast Guard Radio Station St. John's/VON, and Canadian Maritime Command Radio Station Mill Cove/CFH.

International Ice Patrol Ice Bulletins were broadcast by Coast Guard Communications Station Boston/NMF/NIK by CW at 0018 GMT on 5320 and 8502 kHz and at 1218 GMT on 8502 and 12750 kHz. After a two-minute series of test signals, the transmissions were made at twenty-five (25) words per minute and then repeated at sixteen (16) words per minute. Coast Guard Communications Station Boston/NIK/NMF also transmitted a daily radio facsimile broadcast depicting the locations of icebergs and sea ice at 1600 GMT simultaneously on 8502 and 12750 kHz at a drum speed of 120 revolutions per minute.

Ice Bulletins were also broadcast twice daily by U.S. Naval Radio Stations Norfolk/NAM, Londonderry/NST, Thurso/GXH, and Keflavik/NRK on the LCMP Broadcasts between 0500–0600 GMT and 1700–1800 GMT on a wide range of frequencies. Canadian Coast Guard Radio Station St. John's/VON made CW broadcasts at 0000 and 1330 GMT on 478 kHz, and Canadian Maritime Radio Station Mill Cove/CFH also broadcast at 0130 and 1330 GMT on a wide range of low to high frequencies.

Special broadcasts were made by Canadian Coast Guard Radio Station St. John's/VON as required when icebergs were sighted outside the limits of all known ice between regularly scheduled broadcasts. These transmissions were preceded by the International Safety Signal (TTT) on 500 kHz.

Sea ice information services for the Gulf of St. Lawrence, as well as the approaches, from 58°00′W to 66°30′W longitudes including the Strait of Belle Isle to west of Belle Isle itself, were provided by the Canadian Ministry of Transport during the period from December to approximately late June. Ships obtained ice information by contacting the Ice Operations Officer, Dartmouth, Nova Scotia via any east coast Canadian Coast Guard Radio Station.

Supplementary ice conditions and navigational warnings for the Strait of Belle Isle, the coast of Newfoundland, and the Grand Banks were obtained by contacting Canadian Coast Guard Radio Stations: St. Anthony/VCM, Comfort Cove/VOO, St. John's/VON, and St. Lawrence/VCP.

Communications statistics for the period 1 September 1976 through 31 August 1977 are shown in Table 2.

TABLE 2—COMMUNICATIONS STATISTICS

Number of ice reports received from ships	316
Number of ships furnishing ice reports	52
Number of ice reports received from commercial aircraft	1
Number of sea surface temperature reports	1,150
Number of ships furnishing sea surface temperature reports	44
Number of ships requesting special ice information	18
Number of NIK Ice Bulletins issued	195
Number of NIK facsimile broadcasts	97

Of the number of ships furnishing Ice Patrol with ice reports and special sea surface temperature observations, the six most outstanding contributors were:

HMCS HURON/CGXY
M/V BAKKAFOS/TFXQ
M/V STADT WOLFSBURG/DCWE
M/V MONT ROYAL/SFHN
M/V DELCHIM ALSACE/FNRC
M/V ATLANTIC SPAN/SLPN

ICE CONDITIONS, 1977 SEASON

September-December

Due to large departures from the norms, including above average temperatures and prevailing onshore winds along the Labrador coast, sea ice formation and iceberg movement were greatly inhibited. By the end of October, only the northwestern portion of Baffin Bay and the near shore along Baffin Island down to Cumberland Sound were frozen. Throughout November, advancement continued nearshore, where new ice covered the Labrador coast to about 30 miles offshore from Goose Bay north. December closed with the ice just reaching the northern tip of Newfoundland. The northern Strait of Belle Isle was frozen over and sea ice extended 100 to 150 miles offshore along the Labrador coast. Only three icebergs were reported during this period, all by ships approaching the Strait of Belle Isle, and all north of 53°N.

January

The sea ice continued its advance, though slowly due to the continued deviation from normal conditions. By the end of January, new sea ice had formed all the way to Cape Bonavista, Newfoundland, but not extending eastward beyond 54°W. A limited January preseason survey found indications of a very light season (Figure 1). Iceberg distribution along the Labrador coast was well below average, shown graphically by latitude (Figure 2). A total of 34 icebergs were located between 55 and 60°N. No icebergs were sighted south of 55°N. No ship reports were received in January.

February

As meteorological conditions began to normalize in late February with an increased southerly and southeasterly flow, icebergs and sea ice approached the Grand Banks. By mid-February the sea ice had reached Pt. St. Francis and icebergs began to exit from the ice pack. A nearly complete census was obtained during the period 22 February through 6 March on the February preseason survey (Figure 3). About half the normal number of icebergs were sighted with only 145 medium and large icebergs south of 63°N. The relative scarcity of icebergs confirmed that the overall season would be light (Figure 4). The first iceberg south of 48°N was reported in position 47°23′N, 50°55′W on 28 February. By the end of the month, new sea ice extended almost to Cape Race, Newfoundland and as far east as 49°W. The easternmost pack ice (6 to 8 octas of young and first year light) reached 47°30′N, 50°W and extended north northwestward. Only three icebergs drifted south of 48°N during February.

March

The southern and southeasterly flow continued through March with above average temperatures inhibiting sea ice growth. As storm fronts passed through the Grand Banks region, the sea ice was broken up and spread out. Although the leading edge of the consolidated pack began its retreat, the resulting brash and small floes of first year light ice remained in the northern Grand Banks area. Preseason reconnaissance flights on 3, 4 and 5 March encompassing the limits of all known ice south of Belle Isle, located 8 icebergs and 6 growlers (Figure 5). Eight regular reconnaissance flights were made subsequent to commencement of the 1977 season on March 13. Ice observation flights on 18 and 20 March (Figure 6) surveyed the limits of all known ice from 44°N to 48°N. Only 4 icebergs, 2 growlers and 1 radar contact were observed. The easternmost and 1977 season's southernmost extent of sea ice, 47°30′N, 47°30′W and 46°20′N, 51°25′W respectively, occurred about 29 March (Figure 7). During this month, 7 icebergs drifted south of 48°N.

April

By mid-April, conditions began to revert to the abnormals observed in December and January. Predominant onshore winds along the Labrador

coast and southwesterly winds off the coast of Newfoundland accelerated sea ice pack retreat and dispersed the icebergs eastward along 48°N. Ice observation flights on 3, 5, 7 and 10 April surveying the limits of known ice from 45°30′N, to 49°N, (Figure 8), illustrate this phenomenon. Only 3 of the 30 plus icebergs were south of 48°N. The southernmost iceberg of the season was predicted to have reached 45°00′N, 48°40′W on 9 April before melting. The easternmost iceberg of the season was predicted to have reached 47°00′N, 45°40′W on 17 April. As the pack ice continued its retreat, only isolated patches of brash ice remained south of 50°N (Figure 9). The easternmost extent of sea ice observed during the season reached 46°50′N, 46°30′W approximately 15 April. Ice observation surveys on 20, 21 and 22 April found the sea ice limit had retreated significantly with only 6 bergs south of 49°N (Figure 10). By the end of April the sea ice retreated to a very open pack configuration nearshore to 50°W along the Newfoundland and Labrador coasts to Goose Bay. North of Goose Bay 6 to 8 octas of first year light and medium ranged to 120 miles offshore along the coast to Cape Dyer. During the month of April, 12 icebergs drifted south of 48°N.

May

Southwesterly winds off the coast of Newfoundland and predominant onshore winds along the coast of Labrador prevented further ice formation and greatly retarded iceberg movement to the south. Ice observation flights on 30 April, 1 and 2 May confirmed that there were no icebergs south of 48°N and only three icebergs south of 49°N, all grounded (Figure 11). By mid-May the sea ice still extended south of the Strait of Belle Isle primarily in the form of isolated belts and strips. The iceberg distribution continued to remain nearshore with concentrations centered around 49°N, 52°W (Figure 12). Warming temperatures combined with upstream wind-driven currents resulted in a rapid retreat of sea ice to the vicinity of the Strait of Belle Isle by late May, some two to three weeks ahead of normal. These general conditions persisted well into June. Ice reconnaissance flights on 29 and 30 May showed the southernmost iceberg to be at 48°45′N, 51°45′W (Figure 13). All icebergs drifting south of 49°N melted prior to crossing 48°N during May.

June

Early June surveys disclosed a fairly constant number of icebergs located between 50°N and 52°N. As new bergs moved south, some bergs drifted below 49°N and melted. Regular attrition into the Strait of Belle Isle occurred. Sea ice along the Labrador coast consisted of 6 to 8 octas of first year light and medium extending to 100 miles offshore with patches and strings up to 4 octas concentration along the perimeter. One tongue of patches and strings extended out to 53°W along latitude 55°N. By 16 June, there were predicted to be only two icebergs south of 49°N. Ice observation flights on 9 and 17 June surveyed the southern ice limits and the ice conditions near the Strait of Belle Isle (Figure 14). Due to the unusually warm sea surface temperatures during this period, the southern bergs were predicted to melt within two days and those north of 49°N were predicted to melt before crossing 48°N. There had been no confirmed reports of ice south of 48°N since 24 April or south of 49°N since 1 June. Thus, there appeared to be no further threat to the primary shipping lanes for the remainder of the year. The maritime community was notified accordingly and Ice Patrol terminated its services for the 1977 season on 17 June. No icebergs drifted south of 48°N during the month.

July-August

Sea ice deterioration continued at a fairly rapid rate. In mid-July, there was no ice south of Goose Bay, Labrador, and by the end of the month Hudson Strait and Frobisher Bay were ice free. By the end of August, only the area along Baffin Island from Cape Mercy to Lancaster Sound to about 60 miles offshore was not ice free. Although the Ice Patrol services had officially terminated, the Ice Season terminates on 31 August for statistical purposes with the new season beginning 1 September. During July and August many iceberg reports were received from ships on approach to, and traversing the Strait of Belle Isle, the southernmost of which reached 48°50′N, 50°00′W before melting. In all, the 1977 season proved to be very light with a statistical total of 22 icebergs drifting south of 48°N.

Table 3—ESTIMATED NUMBER OF ICEBERGS SOUTH OF LATITUDE 48°N, SEASON 1977

	Sept	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Total*
1977	0	0	0	0	2	8	34	92	91	55	15	3	300
TOTAL 1946–1977	10	2	4	11	64	265	1075	2951	2897	1751	483	100	9,613
AVERAGE 1946–1977	0	0	1	1	2	9	41	100	128	68	22	6	383
TOTAL 1900–1977	256	109	0	0	0	3	7	12	0	0	0	0	22
AVERAGE 1900–1977	3	1	110	91	184	716	3177	7796	9980	5269	1679	489	29,856

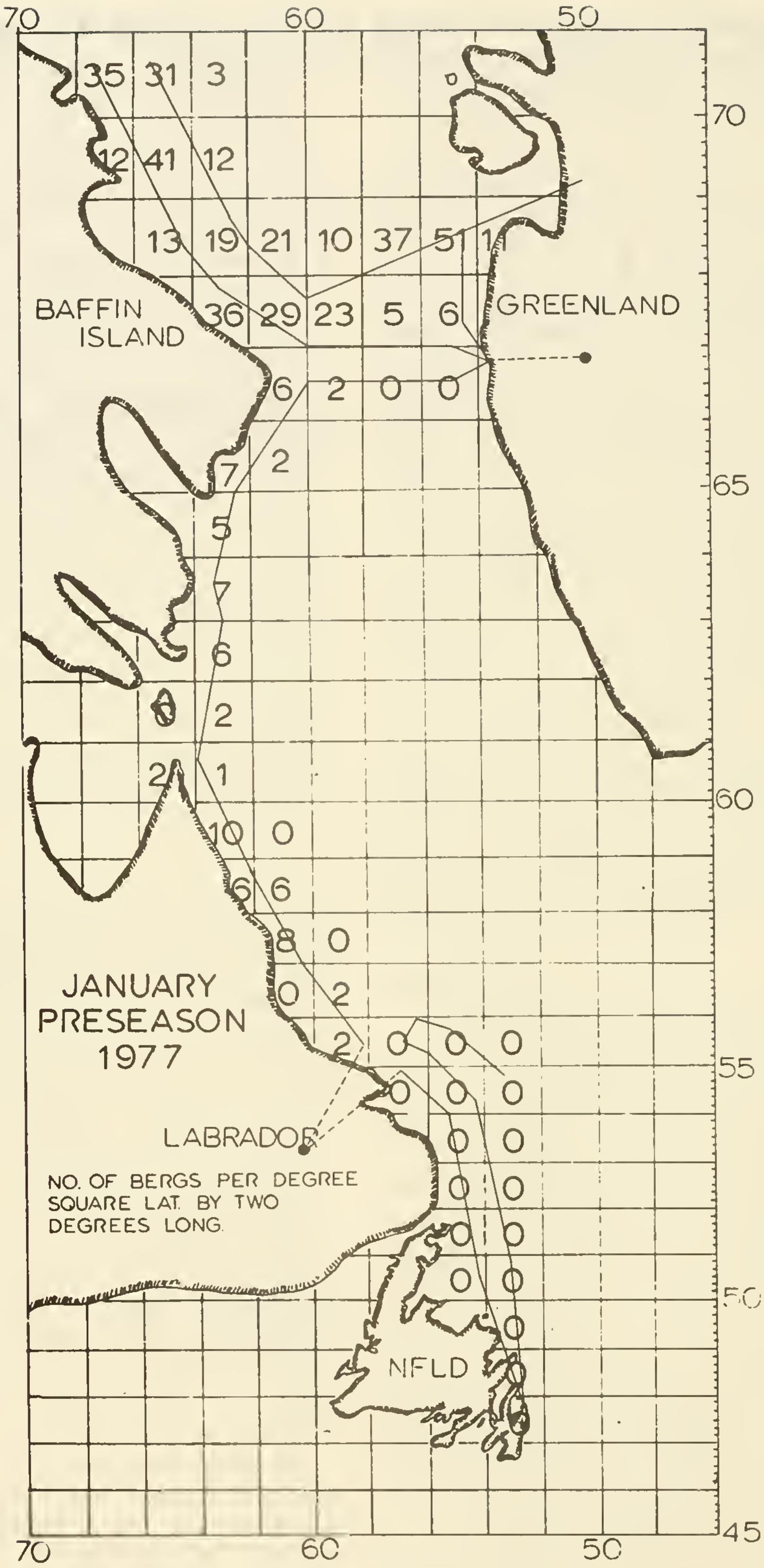
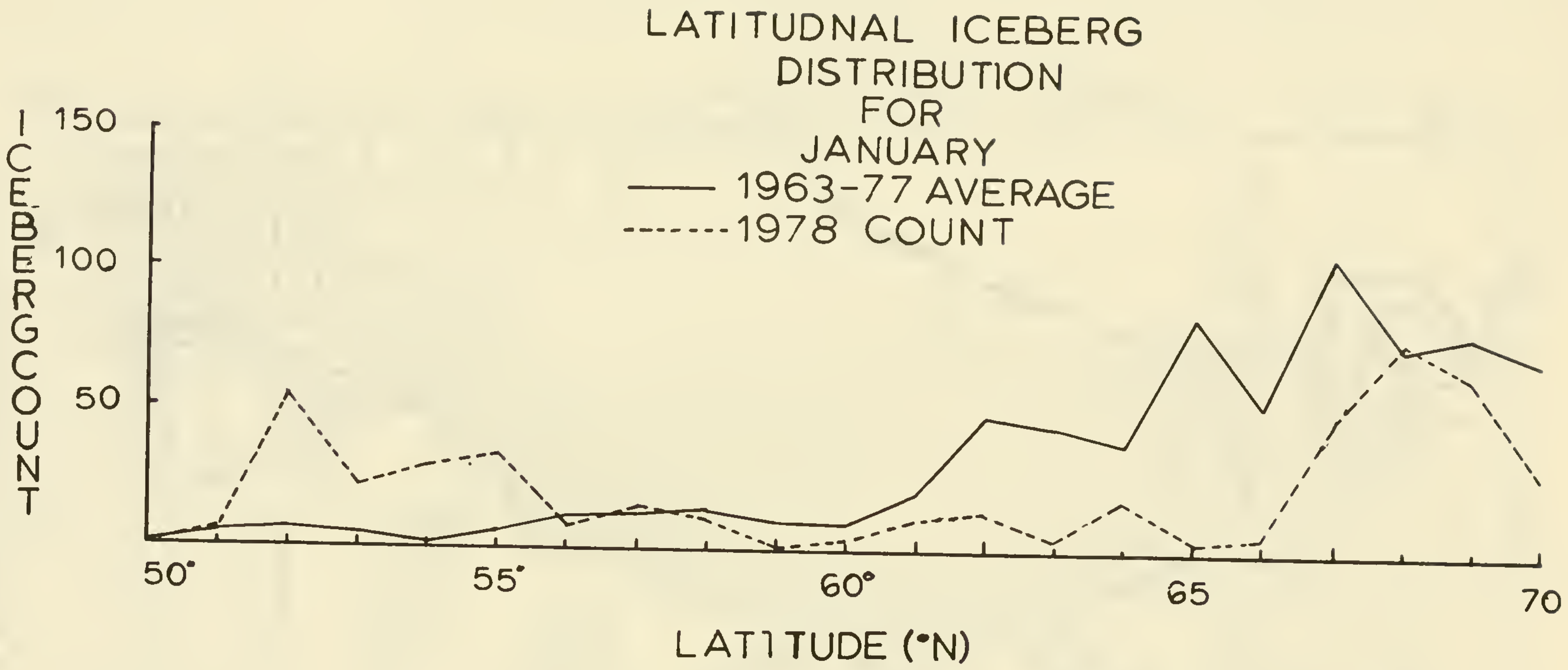


FIGURE 1.—Preseason Ice Survey 17 January 1977.



NOTE: DUE TO LACK OF HISTORICAL DATA THE COUNTS FOR THE AREA NORTH OF 68 N AND EAST OF 60 W WERE NOT INCLUDED IN THE DATA PRESENTED ON THIS CHART.

FIGURE 2.—Latitudinal Iceberg Distribution, JANUARY PRESEASON FLIGHTS.

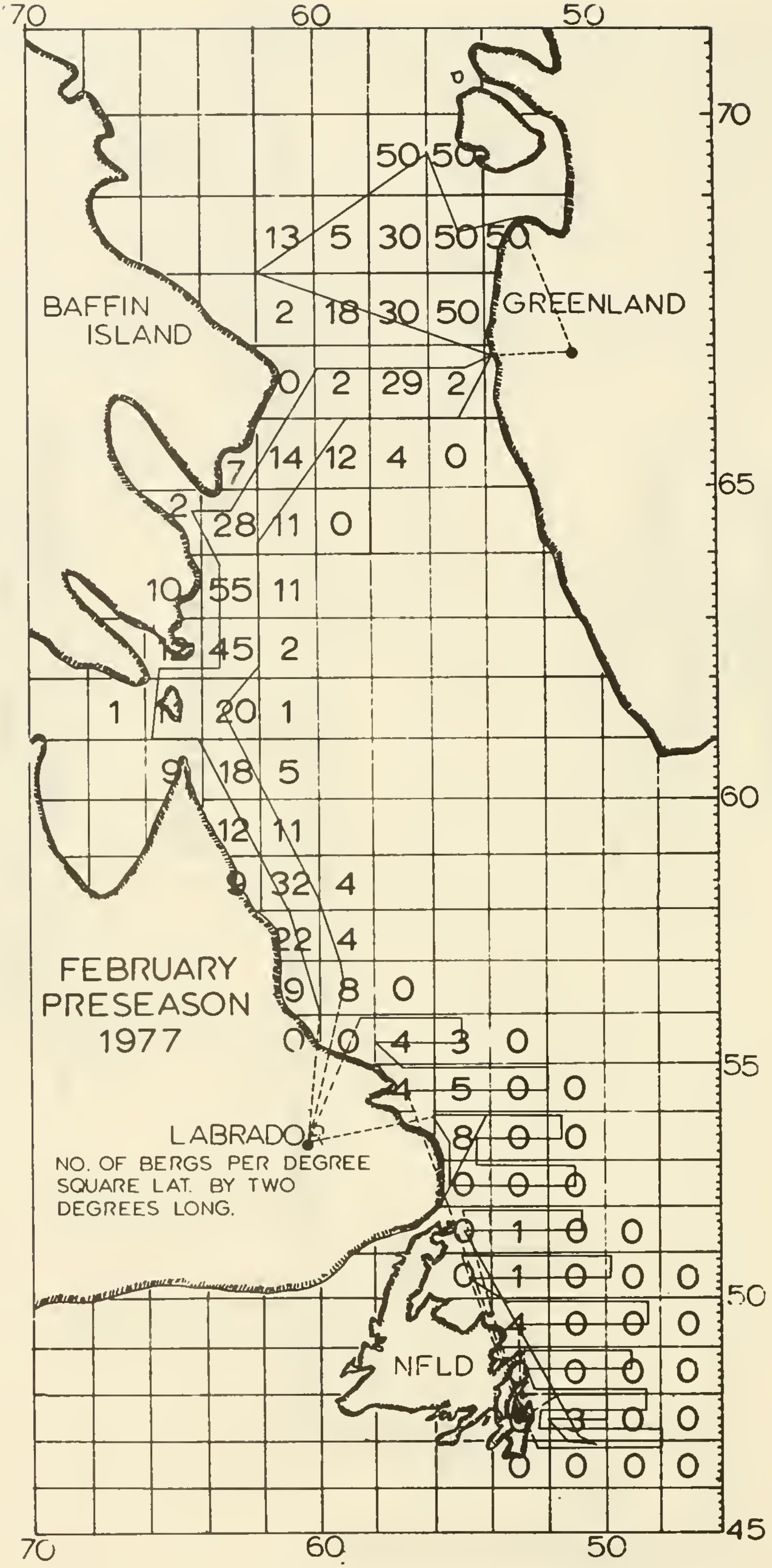


FIGURE 3.—Preseason Ice Survey 22 Feb-6 Mar 1977.

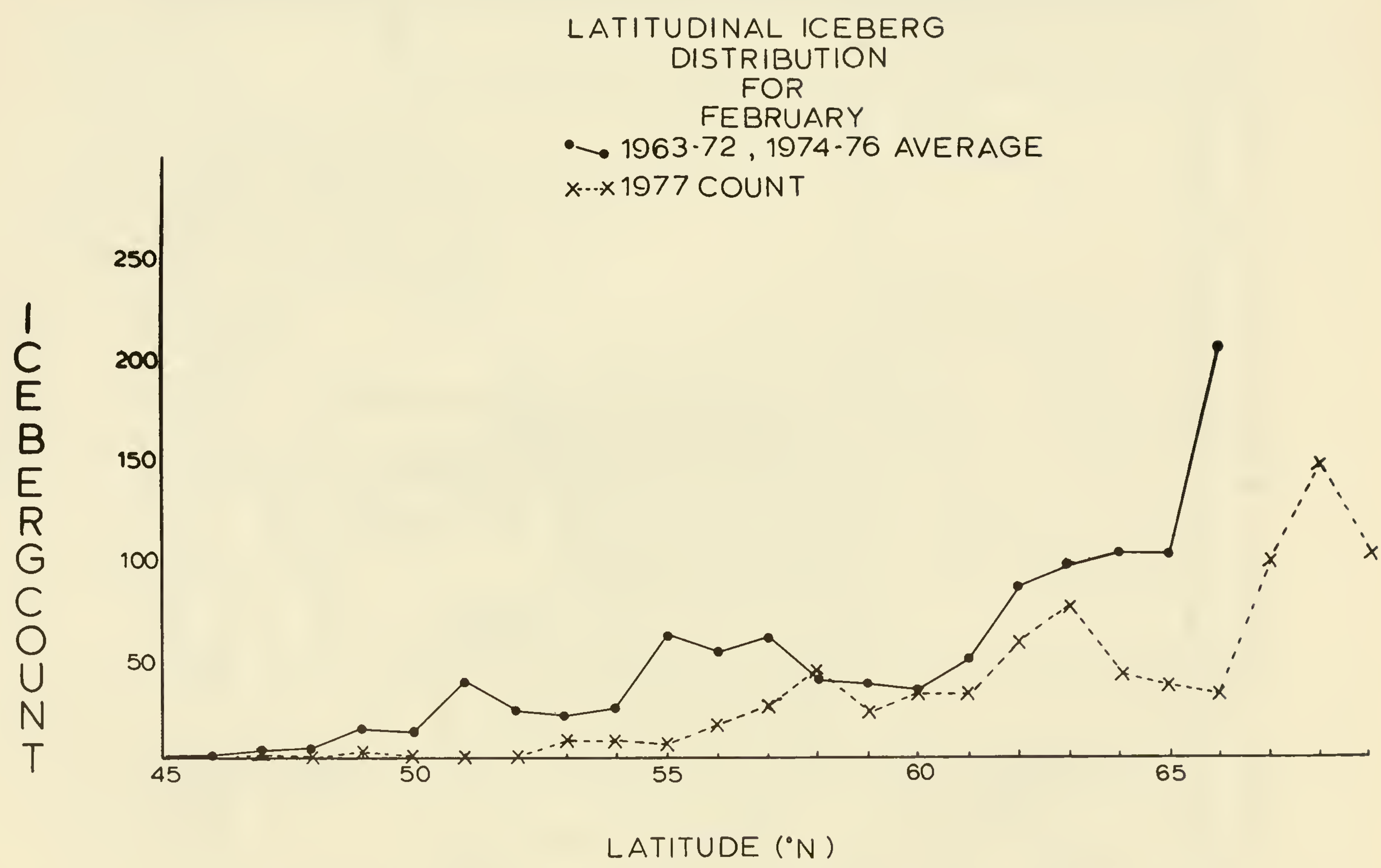


FIGURE 4.—Latitudinal Iceberg Distribution, FEBRUARY PRESEASON FLIGHTS.

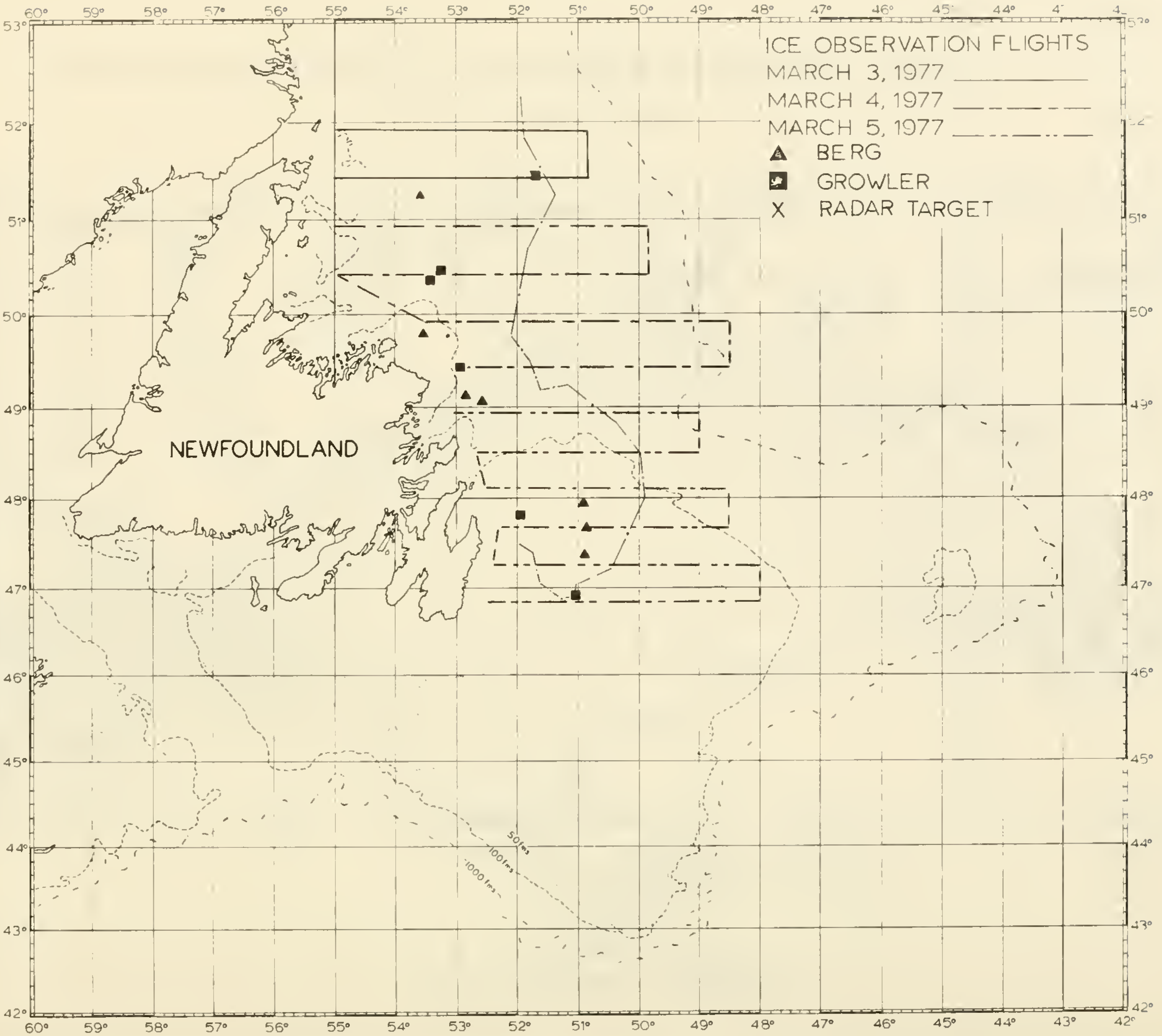


FIGURE 5.—Ice Observation Flights 3, 4 and 5 March 1977.

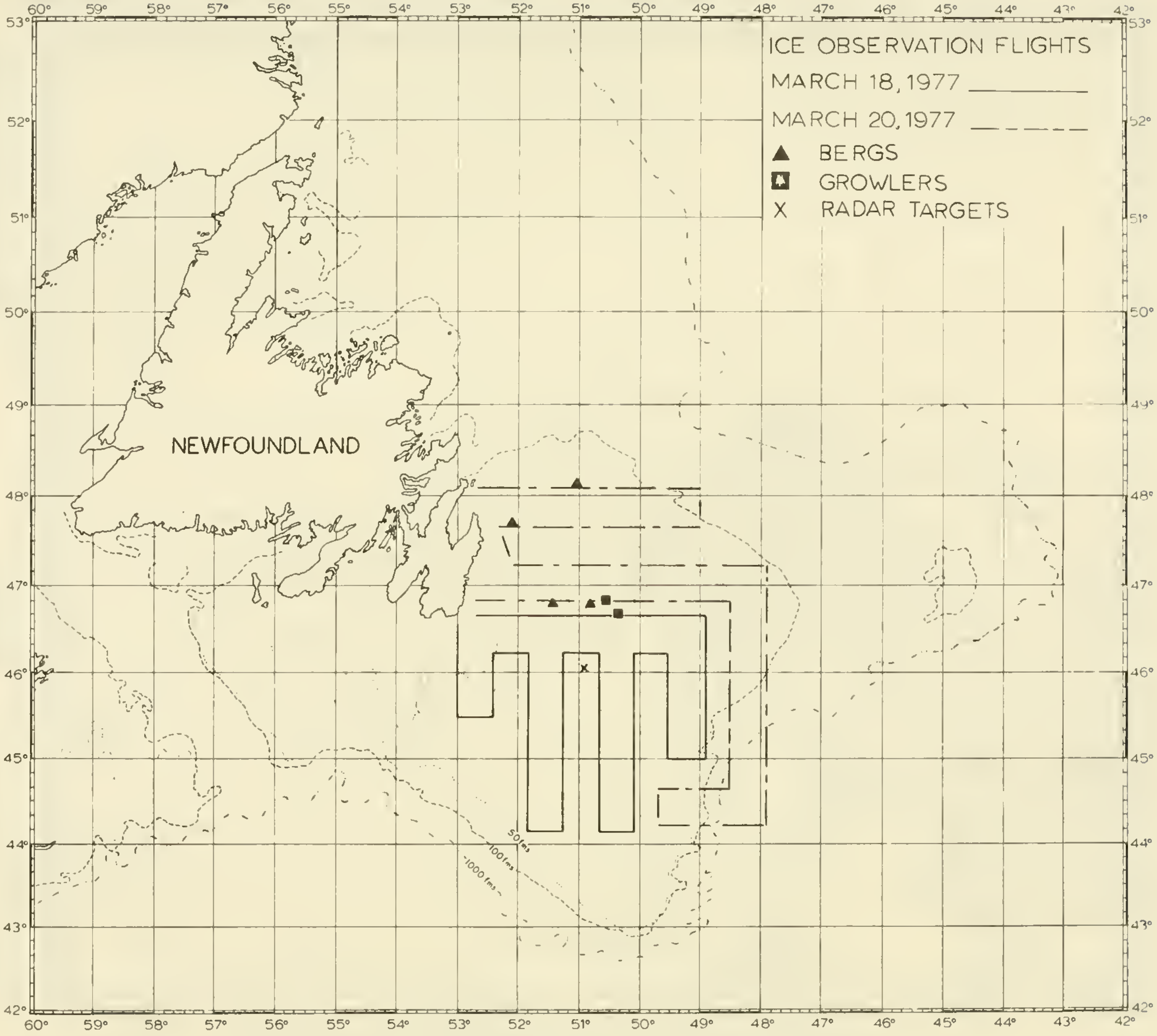


Figure 6.—Ice Observation Flights 18 and 20 March 1977.

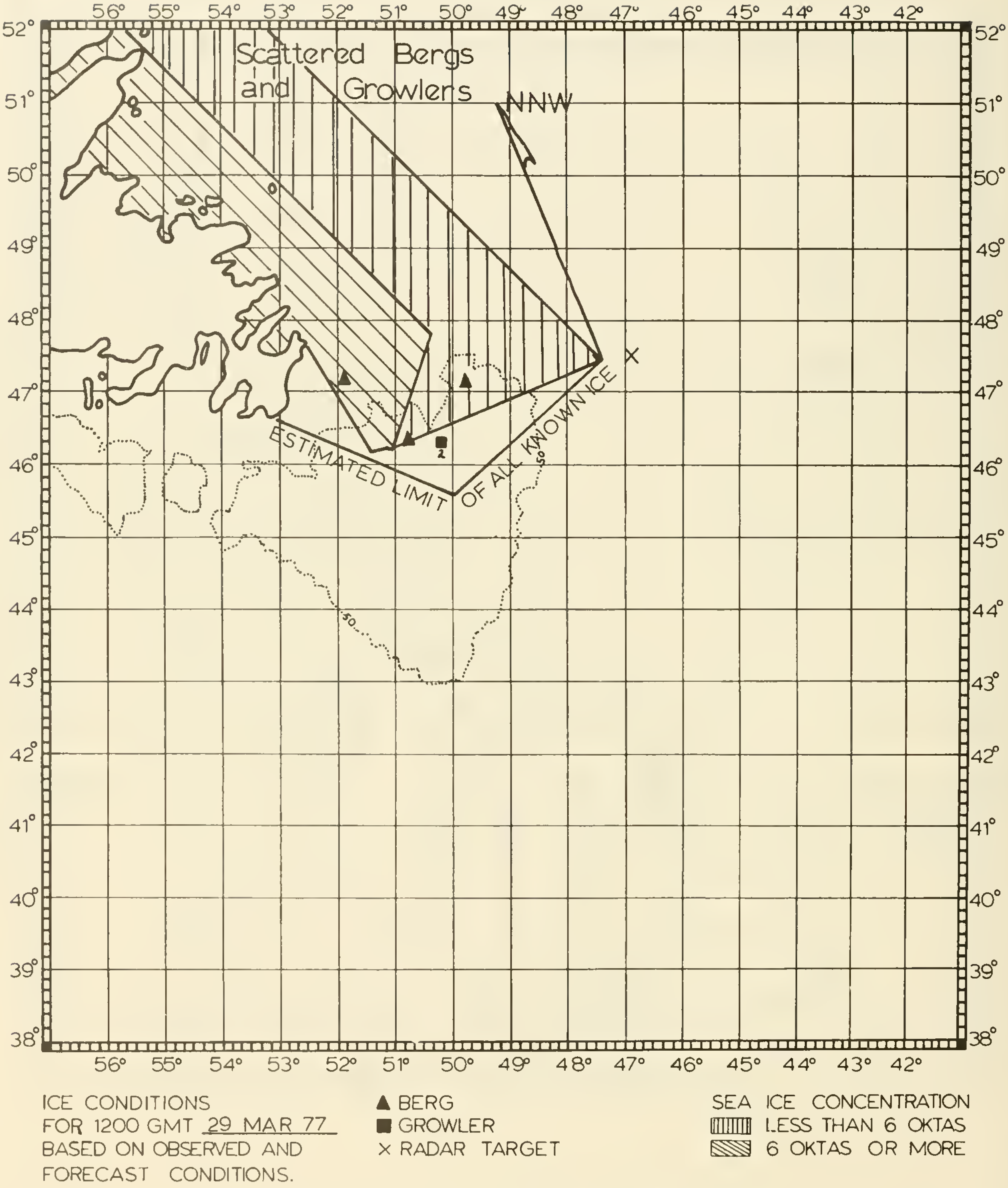


Figure 7.—Ice Conditions, 1200 GMT 29 March 1977.

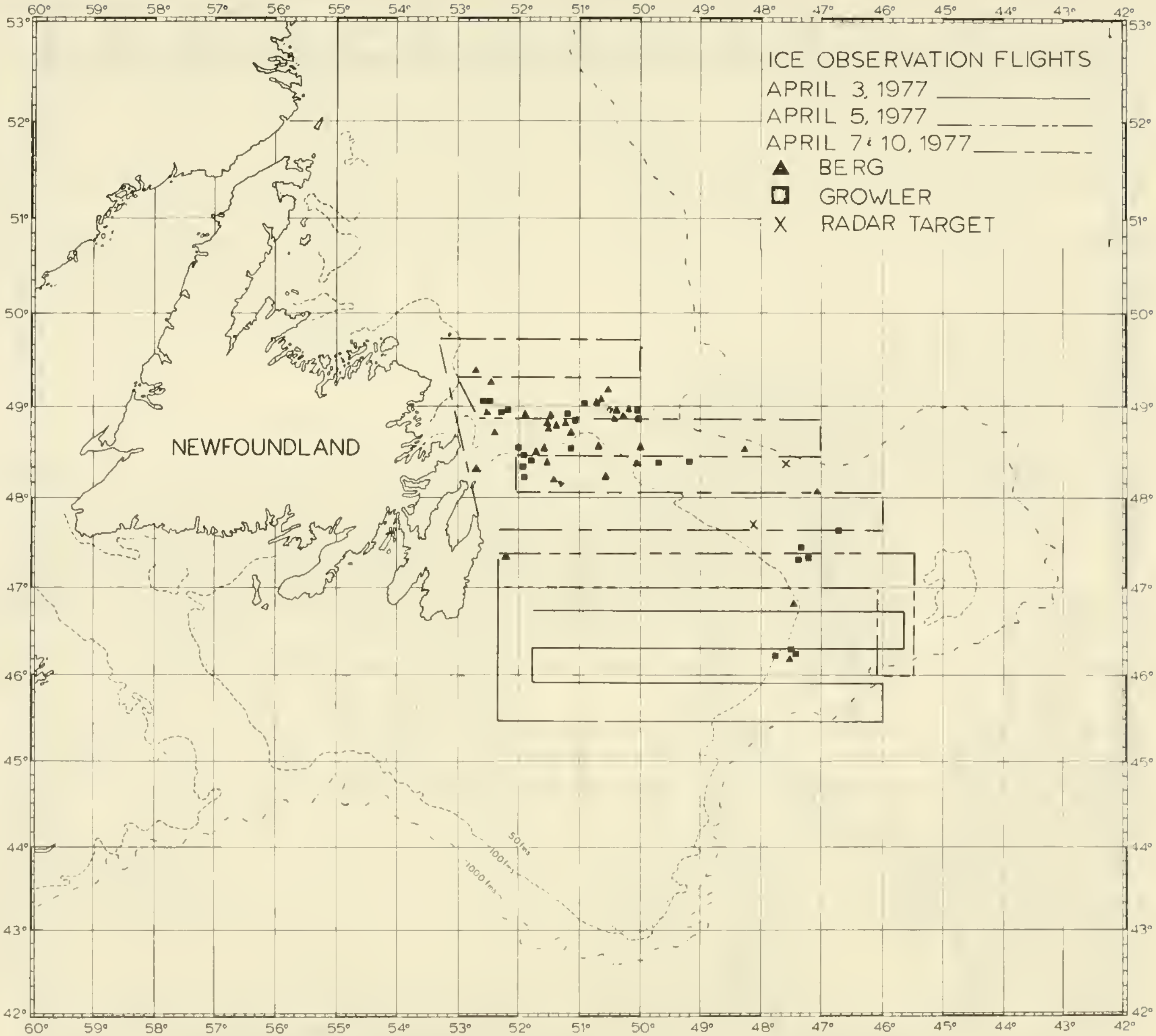


FIGURE 8.—Ice Observation Flights 3, 5, 7 and 10 April 1977.

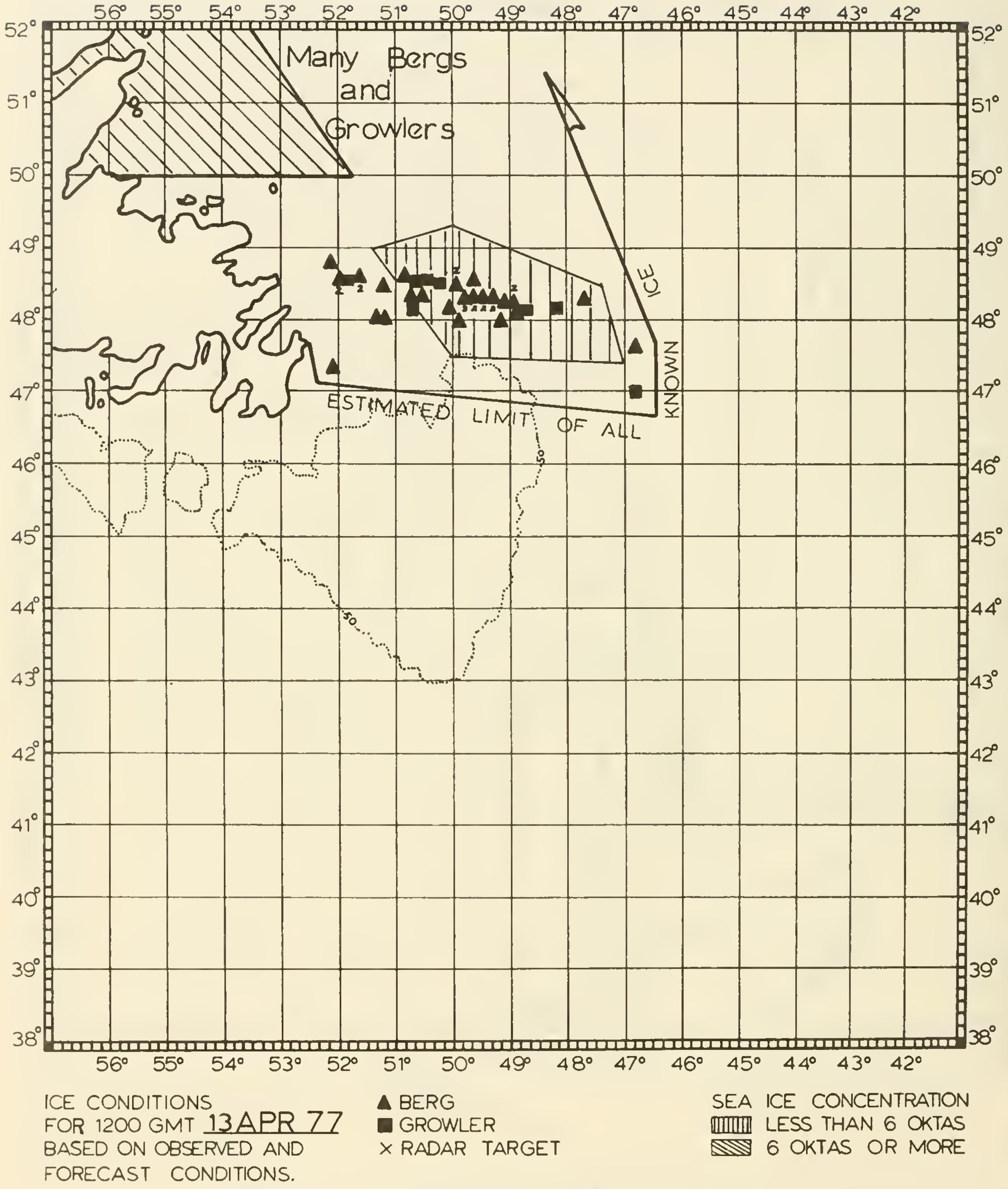


Figure 9.—Ice Conditions, 1200 GMT 13 April 1977.

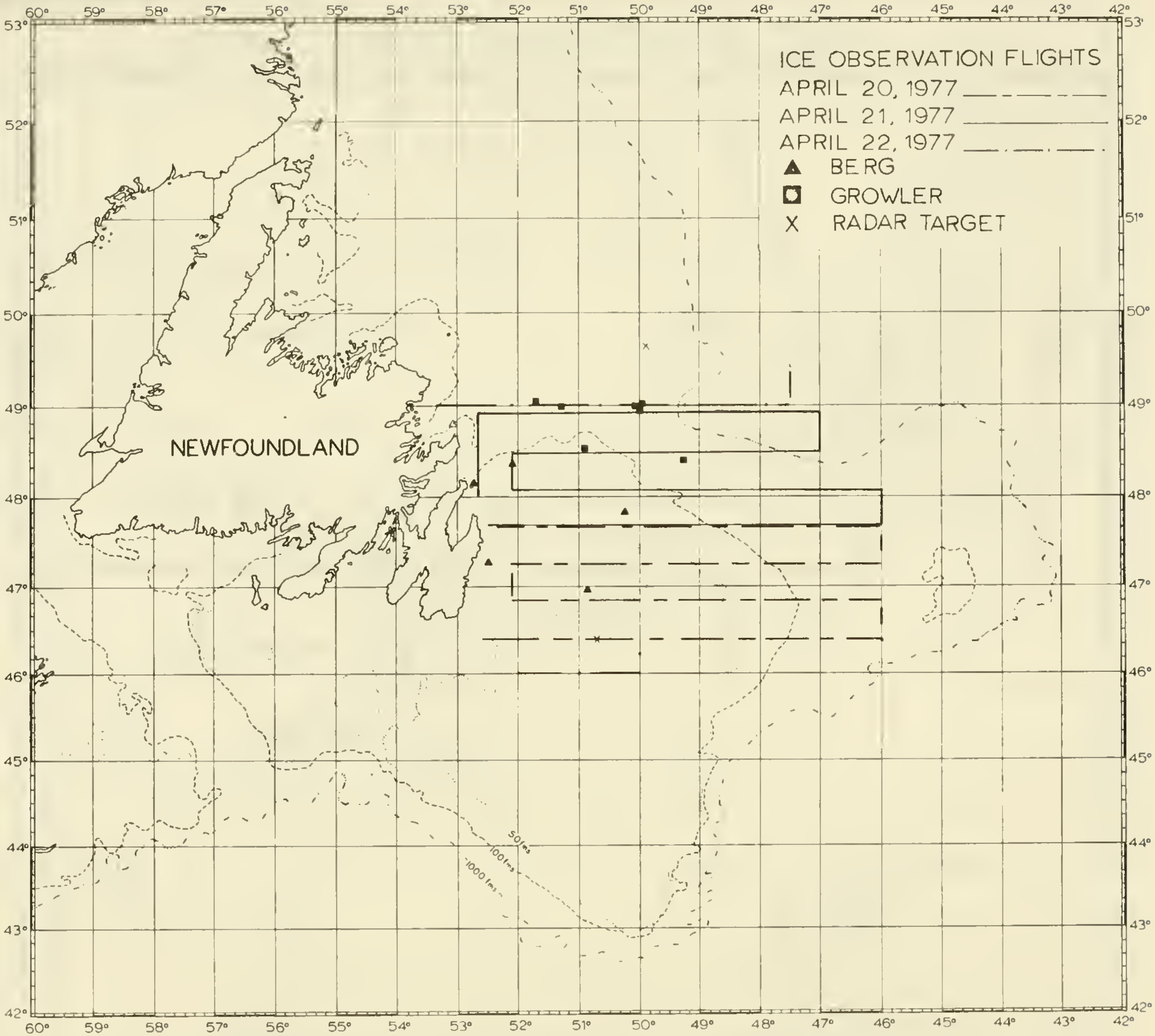


FIGURE 10.—Ice Observation Flights 20, 21 and 22 April 1977.

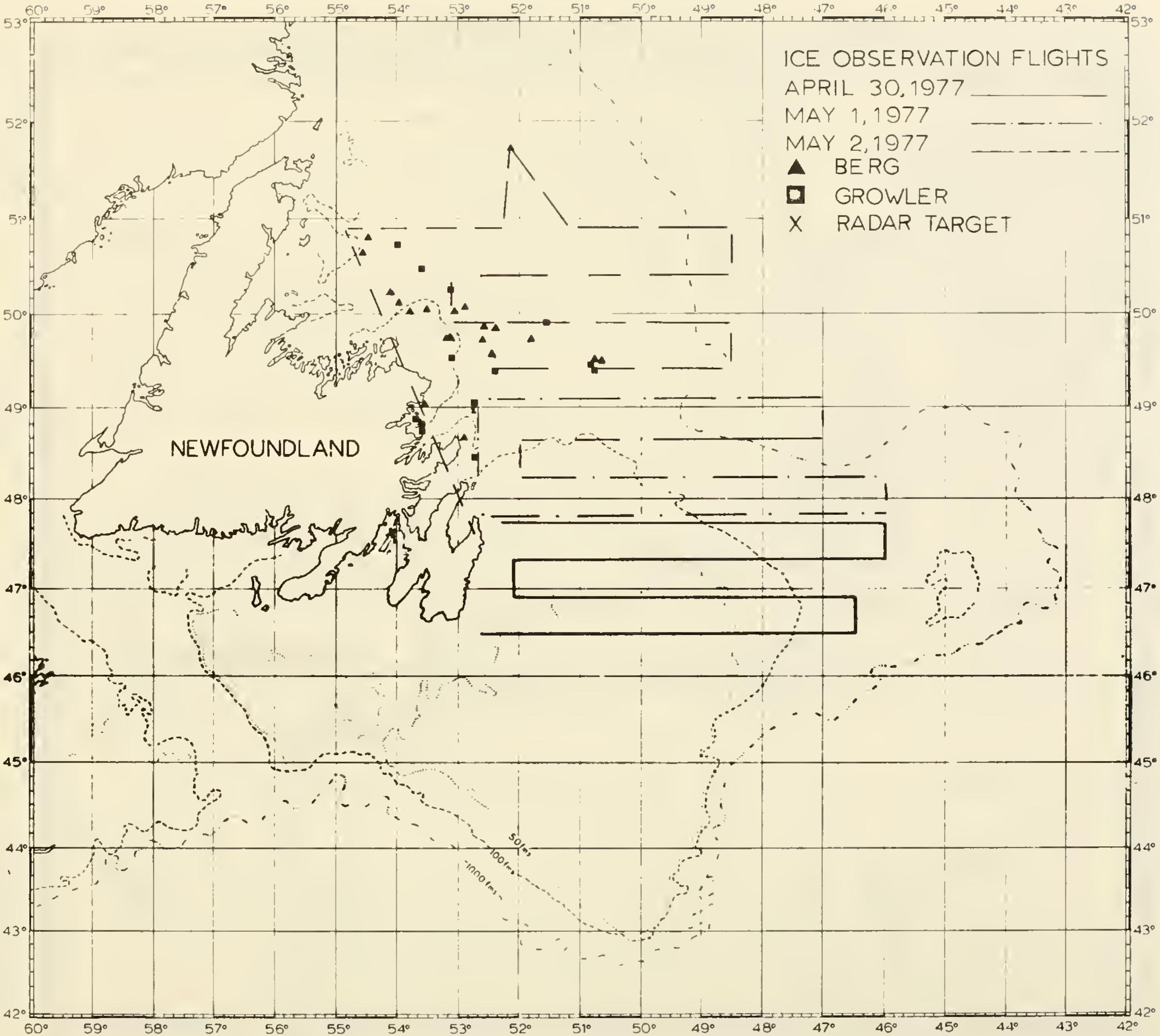
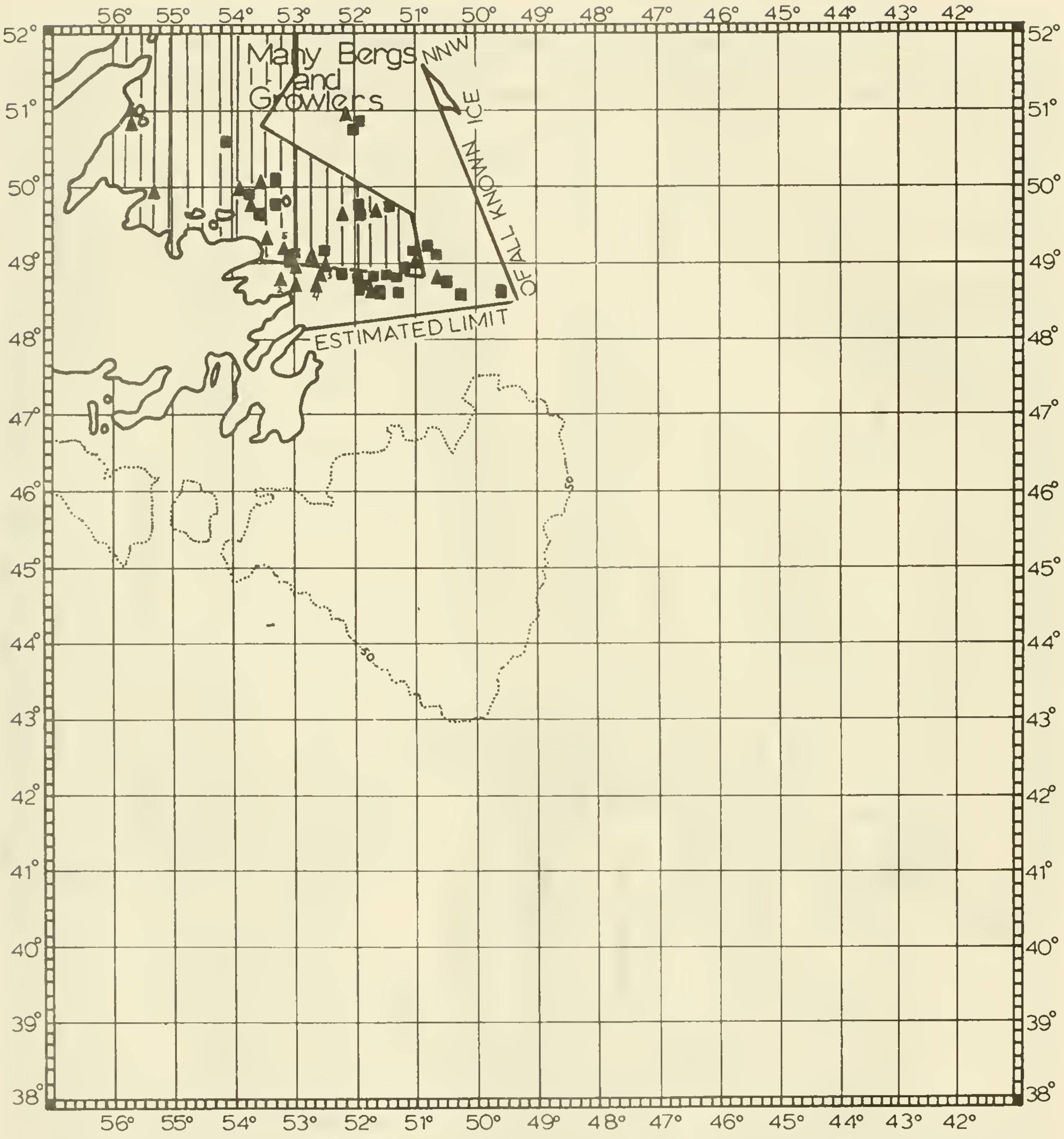


Figure 11.—Ice Observation Flights 30 April, 1 and 2 May 1977.



ICE CONDITIONS
FOR 1200 GMT 14 MAY 77
BASED ON OBSERVED AND
FORECAST CONDITIONS.

▲ BERG
■ GROWLER
× RADAR TARGET

SEA ICE CONCENTRATION
LESS THAN 6 OKTAS
6 OKTAS OR MORE

FIGURE 12.—Ice Conditions, 1200 GMT 14 May 1977.

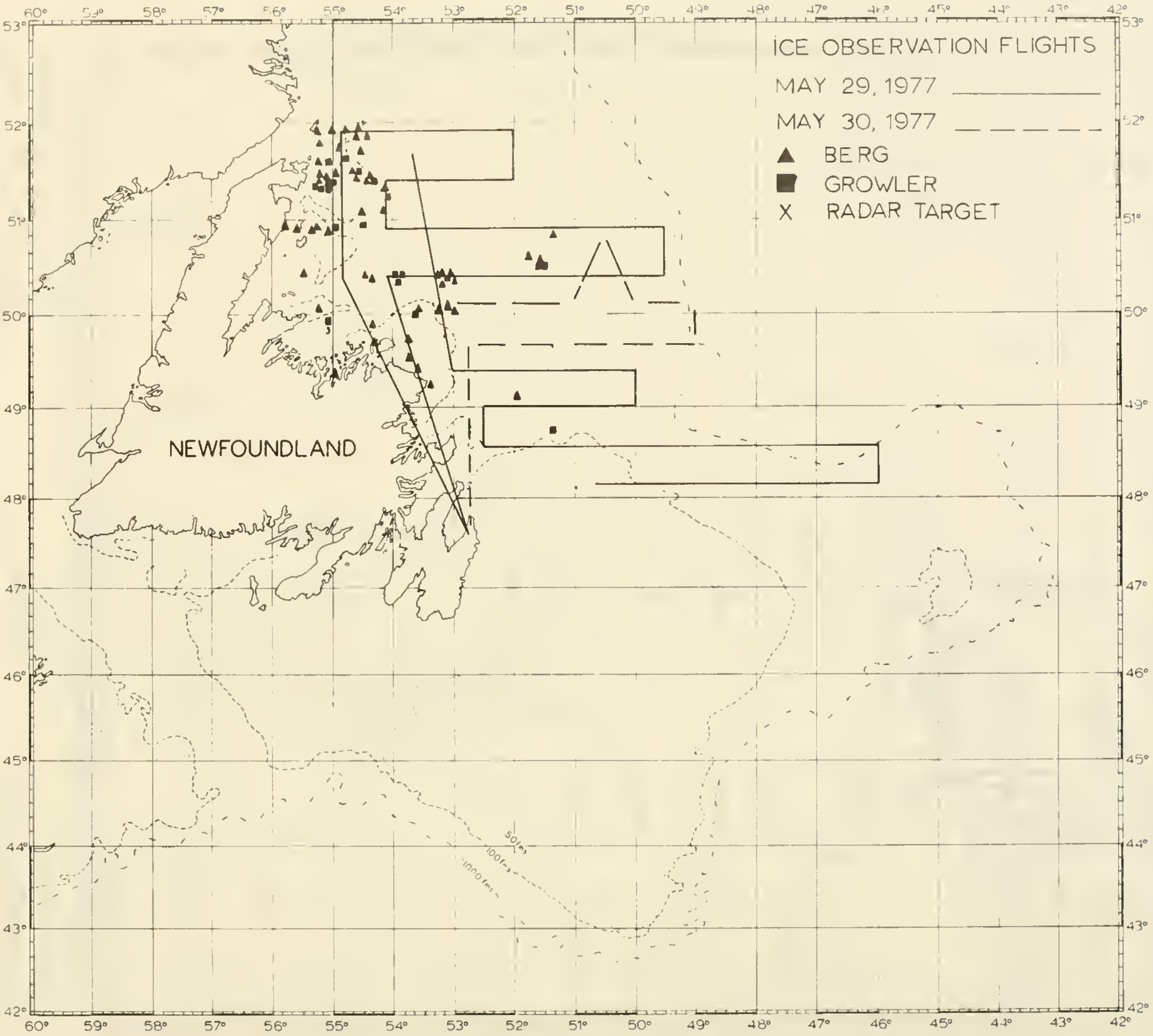


FIGURE 13.—Ice Observation Flights 29 and 30 May 1977.

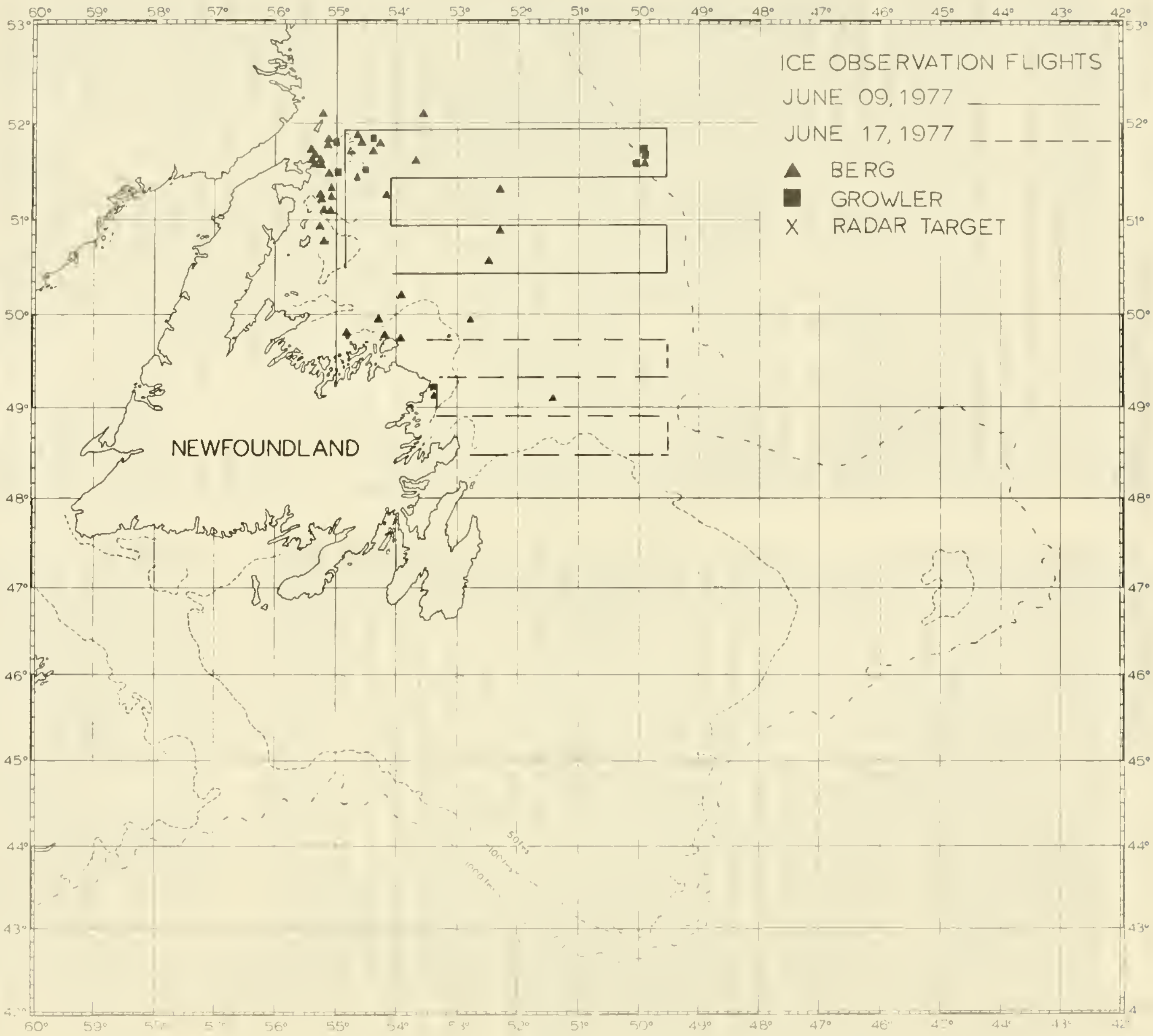


Figure 14.—Ice Observation Flights 9 and 17 June 1977.

OCEANOGRAPHIC CONDITIONS—1977

The International Ice Patrol oceanographic mission in 1977 consisted of two USCGC EVERGREEN (WAGO 295) cruises to the Grand Banks of Newfoundland from 1 April to 1 May and 23 May to 28 June 1977. These provided sea current data from hydrographic surveys for the computer prediction of iceberg drift. Satellite-tracked drogued buoys (BTT's) were used for the second consecutive year to verify and improve operational iceberg drift by making Lagrangian measurements of sea current to compare with estimates obtained by the hydrographic method. As an additional mission of the IIP-2-77 cruise, iceberg and drogued buoy drift data were collected aboard the EVERGREEN for an on-going research project with the objective of improving the iceberg drift model presently used by the International Ice Patrol. Furthermore, a researcher from the University of Washington, Seattle, Washington conducted an investigation examining the physical aspects of iceberg deterioration.

The dynamic topography surveys were accomplished using a Plessey Environmental Systems, Inc., Conductivity/Temperature/Depth (C/T/D), Model 9040, Environmental Profiling System. The data were recorded and processed on the Wang Laboratories, Inc. Model 600-14-TP Programmable Calculator, the Wang Model 629 Dual Tape Drive, and the Wang Counting Interface (Electronics Lab, USCG Station Alexandria, Virginia).

Corrections were applied to the C/T/D temperature and salinity data from measurements made by Nansen bottles with deep-sea reversing thermometers. Salinity was determined from Samples analyzed on the Guildline Instruments, Inc. (Larchmont, N.Y.) Autosal. The temperature quality control values were applied as a constant correction with depth from an average difference between C/T/D System and Nansen bottle for each oceanographic section. The salinity quality control differences were computed for the surface and the bottom, averaged for each oceanographic section. Temperature quality control corrections ranged from +.02°C to +.03°C and salinity corrections ranged from −.07°/₀₀ to +.05°/₀₀.

Operations during the 1977 season included deployment and recovery of two current meter moorings in the Ice Patrol area. One mooring was located in the Labrador Current at 43°47′N, 49°00′W in 493m of water. The second was at 43°20′N, 47°46′W in 3560m of water near the western edge of the North Atlantic Current. The moorings were of 3/16″ coated wire and each included two vector averaging current meters at approximately 100m and 400m depth. The deep mooring also included a film recording depth gauge above the upper current meter.

The current meter mooring design and the method of deployment were similar to that described in the Report of the International Ice Patrol Service in the North Atlantic Ocean, Season of 1976 (CG-188-31, Bulletin 62). The major differences in the mooring were the use of 3/16″ plastic-coated wire for the entire mooring line except the bottom 60 meters leading to the singer, which consisted of 5/8″ plaited nylon. A single 500 lb buoyant float replaced the two 300 lb buoyant spheres used for the 1976 moorings.

Deployment of the moorings occurred on 7-8 April during the first cruise and was accomplished by an anchor last techniques from the fantail of the EVERGREEN using a winch system designed for mooring operations. Recovery of the moorings took place on 24 June during the second cruise. The acoustic release mechanisms were interrogated and commanded to release. The transmitters on the recovery floats were located by an ADF on-board the ship. A problem was encountered in the recovery of the deep mooring where the acoustic release failed to respond to repeated interrogation, although it ultimately did release successfully.

The current meters on the shallow mooring provided good records for the entire deployment period, yielding 77 days of data from each meter.

The current meter at 100m depth on the deep mooring yielded 30 days of data before a partial flooding of the instrument occurred, while the lower meter malfunctioned and yielded no usable data. The depth gauge on the deep mooring flooded and no data were obtained.

Initial analysis of the data reveals average velocities in the Labrador Current that are parallel to the bottom contours with magnitudes of 46 cm/sec at 120m depth and 18 cm/sec at 385m depth. Spectral analysis indicates that the major variations of the current occur at a time scale of 12 to 16 days and that these variations are coherent with the local wind field.

Two BTTs (Buoy Transmitting Terminal) were used in 1977, platform identifications 0647 and 0671. These were of the same type as those used during IIP–76 (CG–188–31).

Buoy 0647 was deployed on 13 April 1977 at 2100Z in position 47°02′N, 47°15′W. It was allowed to drift until 1815Z 22 April when it was recovered in position 45°27′N, 47°26′W (figure 15), a Handar Inc. automatic direction finder, Model 602A was used to locate the buoy and to test the electronic package before deployment.

This buoy provic l two important inputs to CIIP. The first was the speed of the Labrador Current. This current was measured using hydrographic survey techniques. This survey measured a maximum velocity of 44 cm/sec. The buoy showed that the speeds were closer to 60 cm/sec, an important difference when drifting icebergs. The second important input was obtained from the direction of the buoy's drift. The hydrographic survey showed a section of the Labrador Current was changed from its normal southerly direction and was flowing in a northeasterly direction. It was not known for certain that this was an accurate picture of the current. When the buoy entered this area it also swung back towards the northeast and followed the direction indicated by the survey very closely. This information allowed CIIP to have a much higher confidence in their product.

Buoy 0671 was deployed on 20 April 1977 at 2351Z, but stopped transmitting the next day. Buoy 0647 was redeployed on 31 May 1977 at 1242Z but stopped transmitting on 2 June. At the time of the apparent failure, both buoys were indicating good battery voltages and for several days the cause of the failure was unknown. However, when the EVERGREEN returned to St. John's, Newfoundland, personnel from the fishing vessel Cape Wrath II returned Buoy 0647. It had become entangled in the ship's fishing nets. The use of BTT buoys in areas where fishing is extensive will have to be used with the understanding that the mortality rate will be higher than in remote regions of the ocean.

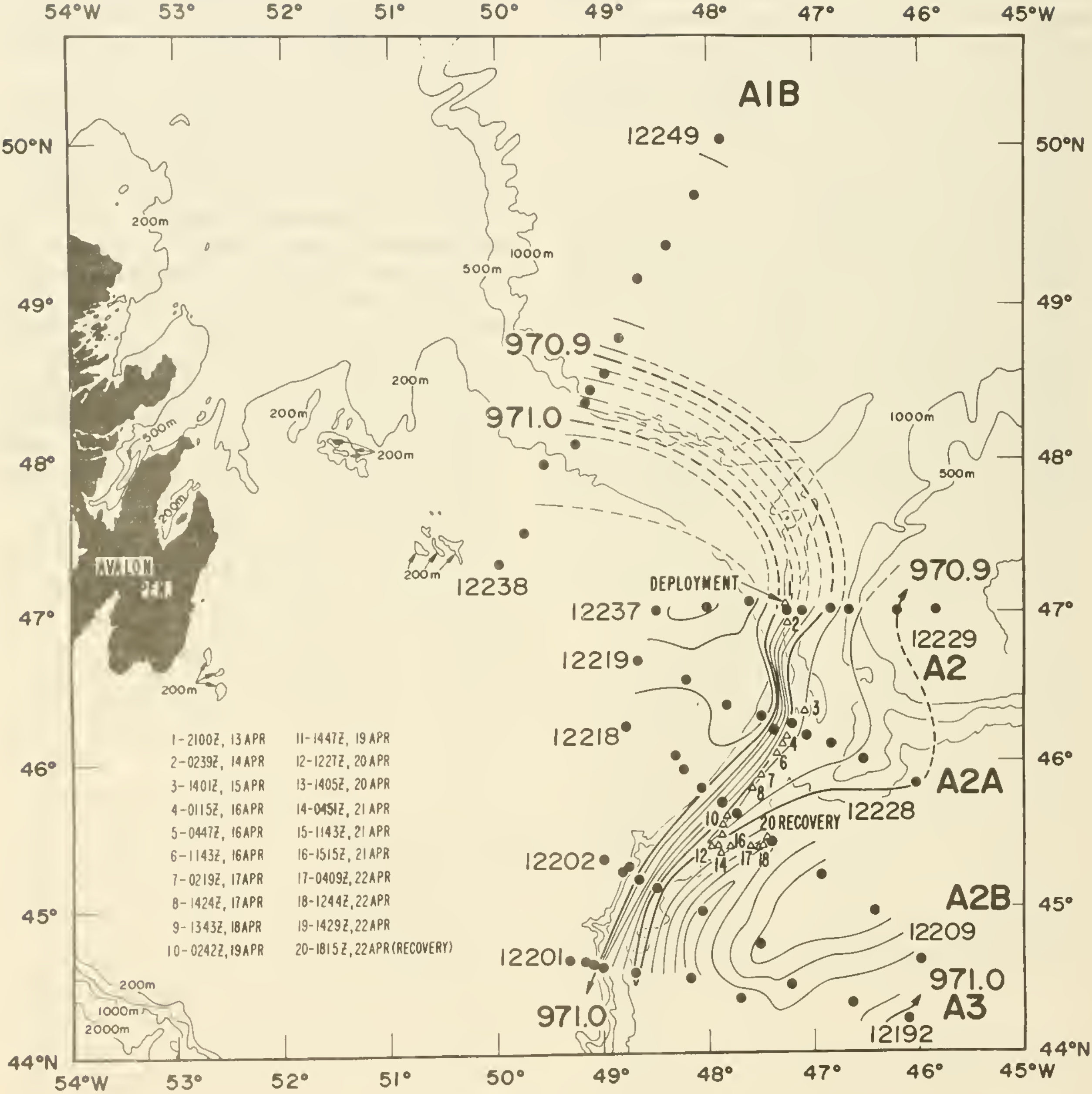


Figure 15.—Plot of BTT 0647.

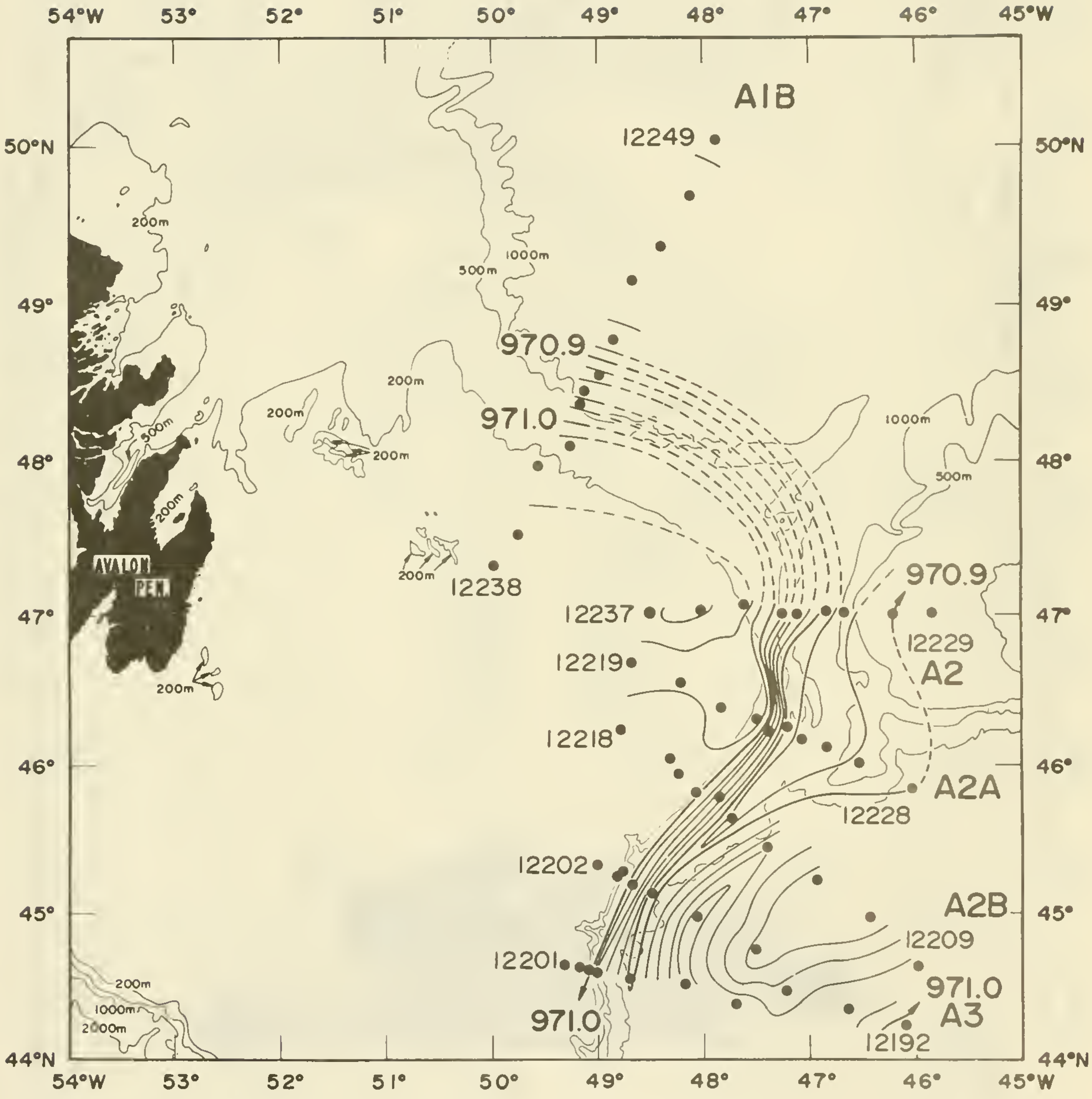


FIGURE 16.—Sea surface dynamic topography (dynamic meters) relative to the 1,000 decibar level, CGC EVERGREEN 8–14 April 1977. Contour interval is 2 dynamic centimeters.

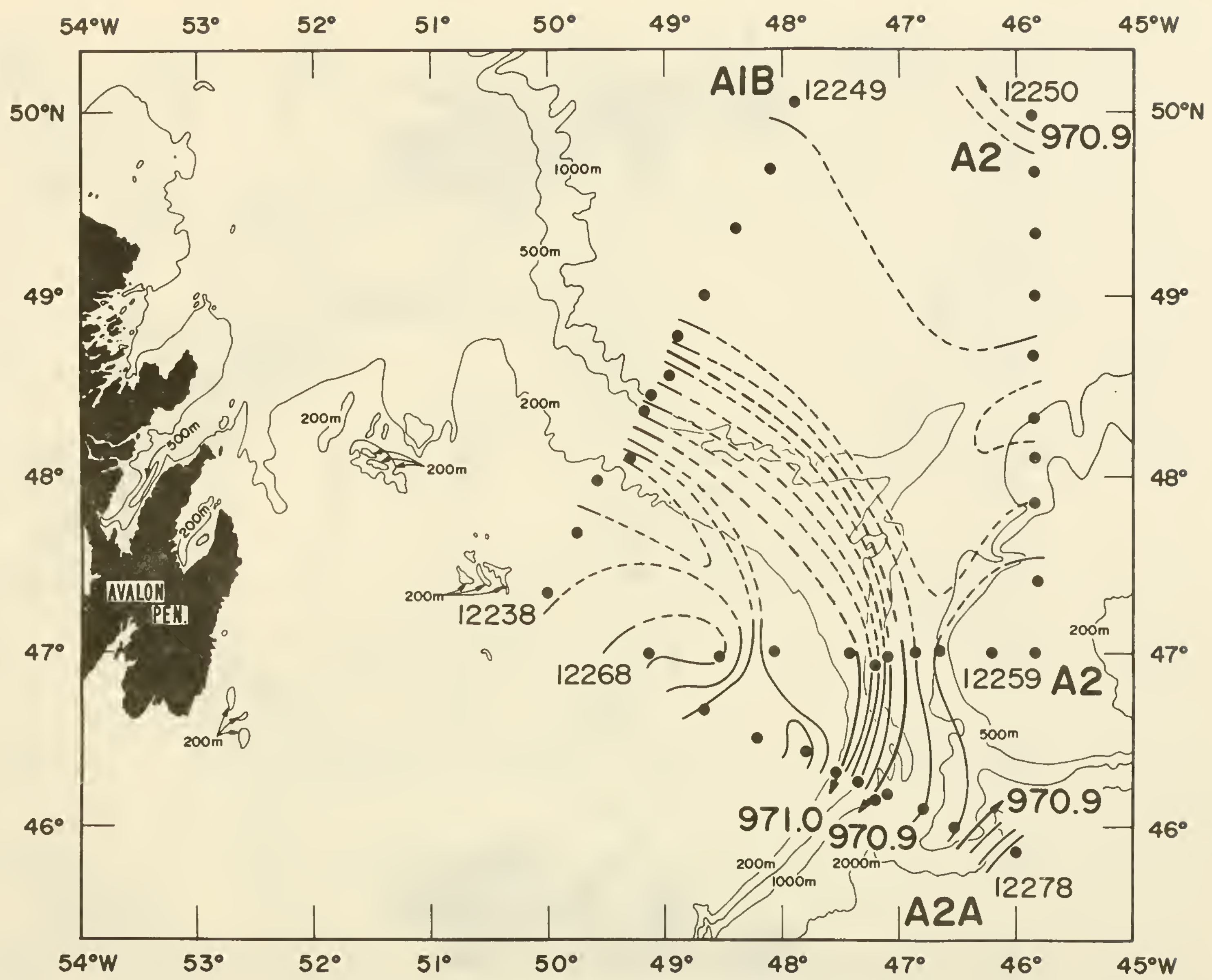


Figure 17.—Sea surface dynamic topography (dynamic meters) relative to the 1,000 decibar level, CGC EVERGREEN 17–22 April 1977. Contour interval is 2 dynamic centimeters.

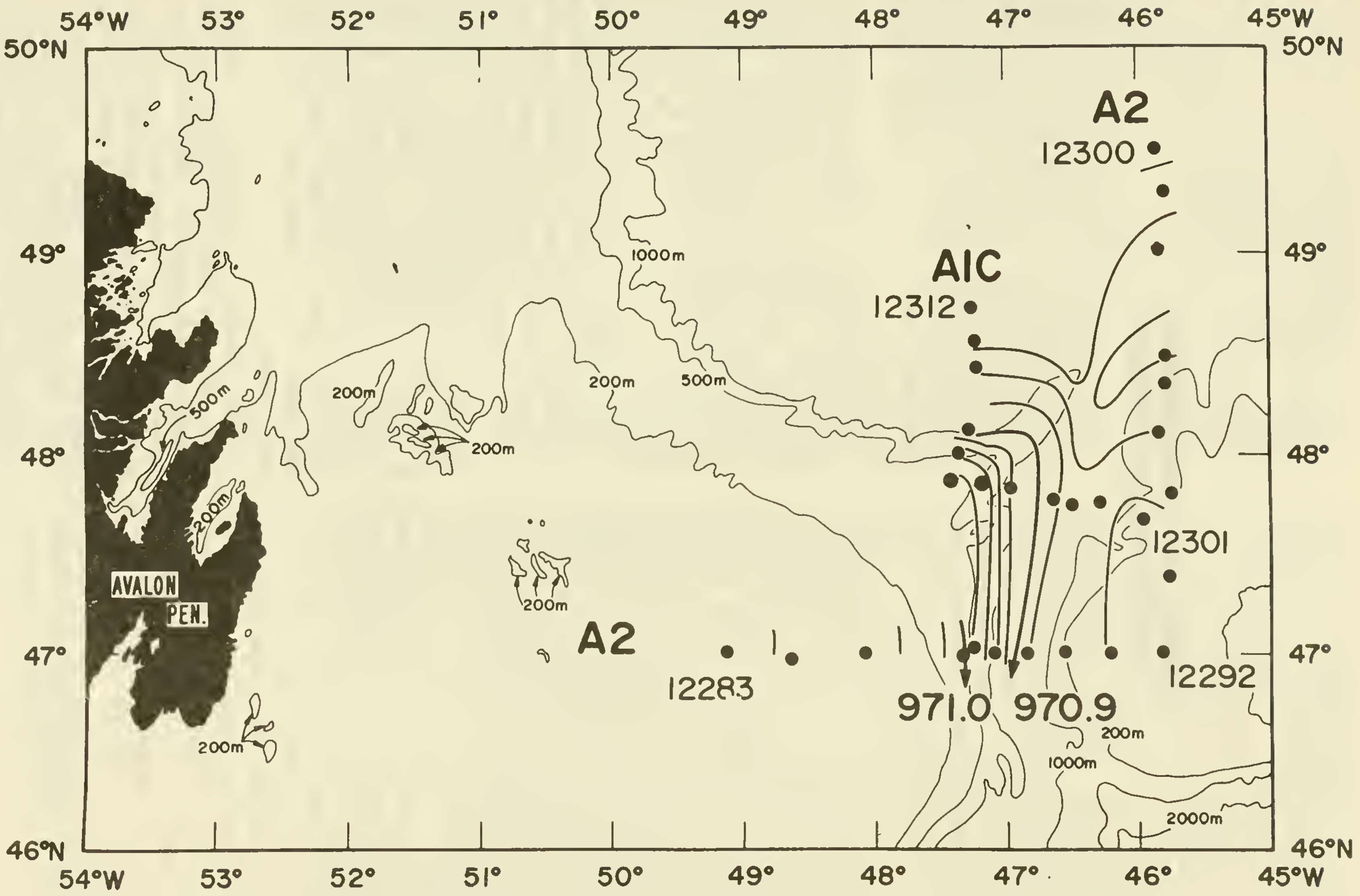


FIGURE 18.—Sea surface dynamic topography (dynamic meters) relative to the 1,000 decibar level, CGC EVERGREEN 27–31 May 1977. Contour interval is 2 dynamic centimeters.

ICEBERG AND ENVIRONMENTAL CONDITIONS 1977 SEASON

There are several complex interrelated parameters which account for the numbers of icebergs that will reach the Grand Banks during an ice season. One of the least important of these is fluctuations in the annual productivity of the west Greenland glaciers from which these bergs originated. With an excess of 10,000 icebergs calved each year from these glaciers, there is certainly a sufficient iceberg inventory in Baffin Bay during any year to produce a severe iceberg season in the vicinity of the Grand Banks. There are four factors or conditions primarily responsible for determining the number of icebergs that will drift toward and ultimately survive to reach the Grand Banks. These are the intensity or volume transport rate of the Labrador Current; the direction, magnitude and duration of the prevailing winds encountered by the icebergs during their drift; the extent of the sea ice cover available to protect the icebergs; and, finally, the environmental conditions to which the iceberg is exposed when out of sea ice (i.e., air and water temperatures, wave action). Abnormalities in any of these could be responsible for either a very light or heavy iceberg season off Newfoundland.

The 1977 Ice Season was one of the lightest seasons on record with an estimated total of only 22 icebergs drifting south of 48°N. This was significantly less than the 1946–1976 average of 300 icebergs and the median of 107.

The sea ice observations during the 1977 Season are discussed in the Ice Conditions section of this publication. The Oceanographic Conditions section reviews features of the Labrador and North Atlantic Currents as recorded by the Ice Patrol research vessel EVERGREEN. Other environmental parameters responsible for the scarcity of icebergs in the vicinity of the North Atlantic shipping lanes are discussed in the following paragraphs.

The January and February preseason surveys as discussed in the Ice Conditions section referred to Figures 1 and 3, which gave the first indications of a light season. The partial January survey and the nearly complete February census found a relatively scarce population of icebergs having the potential of reaching the Grand Banks when compared with the normals in Figures 2 and 4.

Figures 19a through 19l depict the normal and 1977 sea surface pressure patterns for September 1976 through August 1977. When interpreting the figures, the isobars, drawn as heavy solid lines, provide an average wind direction. Winds tend to blow nearly parallel with the isobars, counterclockwise around low pressure and clockwise around high pressure cells in northern latitudes.

The predominant characteristic of the monthly average sea surface pressures was the meandering Icelandic Low. The October position of the Low was located near its climatological mean but more intense than normal. This Low began a westerly drift during November and December across the Labrador Sea, filling during December. Nearing normal intensity, the Low was centered near Belle Isle in January 1977. The resulting flow patterns were southerly during October, slowly shifting to the north-northeast for January. This shift slowed the icebergs' southerly drift and caused them to bunch between 65°N and 70°N (Figure 1).

During February, the Icelandic Low began to deepen once more, slowly returning to its climatological normal position for March while retaining its intensity. The Low filled dramatically in April and had drifted again to over the Labrador Sea. During May, the Low intensified again and continued to move to a position just north of Notre Dame Bay, Newfoundland. The shift of the Low released the icebergs previously retained in January, and caused them to begin drifting

south again during February and March. The position of the Low in April caused onshore winds and resulted in a large number of iceberg groundings along the Labrador Coast. During May, the winds along 48°N were from the southwest causing a pool of icebergs to form above 48°N, impeding more southerly drift. Here unprotected by the retreating sea ice and subjected by warming spring temperatures, the iceberg population began to thin rapidly.

The Icelandic Low continued to move westward and fragmented in June. Continued southwesterly flow over the entire Newfoundland and Labrador coastlines caused northerly and easterly drifts for those few surviving icebergs. These icebergs melted rapidly in the open water and with warm air temperature prevailing as summer approached.

The 1977 surface pressure gradients are graphically shown in Figure 20, with a comparison to their 1946–1976 normals provided. Surface pressure gradients are the differences in surface pressures between two geographical points. The steeper the gradient or the more rapid a change in pressure, the higher the wind velocity will be; the opposite is true for shallower gradients or milder pressure changes. The Ice Patrol has established six such gradients from the Davis Strait off the Labrador and Newfoundland coasts in an attempt to better understand the wind magnitudes and primary wind directions flowing along the main iceberg drift routes heading toward the Grand Banks region. These gradients are depicted in Figure 21 and 22.

The most obvious and significant feature of the gradients in Figure 21 is the low valley that occurred in gradients 1, 2 and 3 during December 1976 and January 1977. These valleys indicate the strong northwesterly flow incurred by the Icelandic Low moving toward Newfoundland and explain the impeded southerly drift of the early season icebergs. The large peak in February and March shows the return of strong southwesterly wind flow encouraging drift to the south. Once again, flow is reversed in April and continues for the remainder of the season as shown by the shallow valleys. Hence the decreased influx of icebergs. The southerly winds across gradient 3 during this period brought warm air into the region accounting for the retreat of sea ice and melting of the trapped icebergs above 48°N. The very slight easterly winds from late May through the end of the season, as shown in gradient 4, did not encourage much easterly iceberg drift and thus, most icebergs remained close to shore.

Air temperatures over Labrador and east Newfoundland show various departures from climatological averages throughout the ice season, all stemming from the abnormal positioning of the Icelandic Low. Generally, the winter temperatures were at or slightly above normal in the northerly regions, cooler than normal in the south. For the spring and early summer months, temperatures were generally cooler than average to the north, and near normal in the south. The graphs in Figures 23 and 24 represent the cumulative frost-degree-days and melting-degree-days, respectively. Locations of the seven preselected shore stations are shown in Figure 20. A frost-degree-day is defined as one day mean of one degree Fahrenheit below 32°F, and a melting-degree-day is defined as one day mean of one degree Fahrenheit above 32°F. That is, a daily averaged temperature of 12°F equals twenty frost-degree-days, and a daily averaged temperature of 42°F equals ten melting-degree-days.

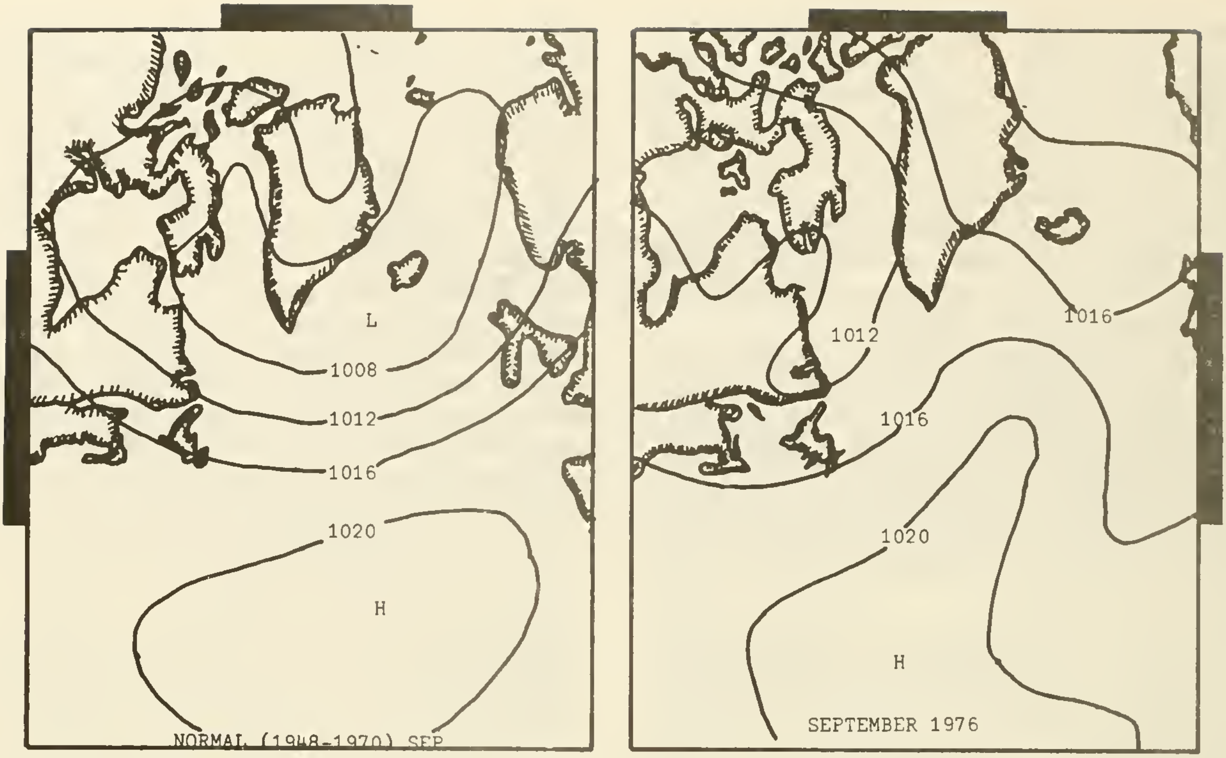


FIGURE 19a.—September 1976 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

FIGURE 19b.—October 1976 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

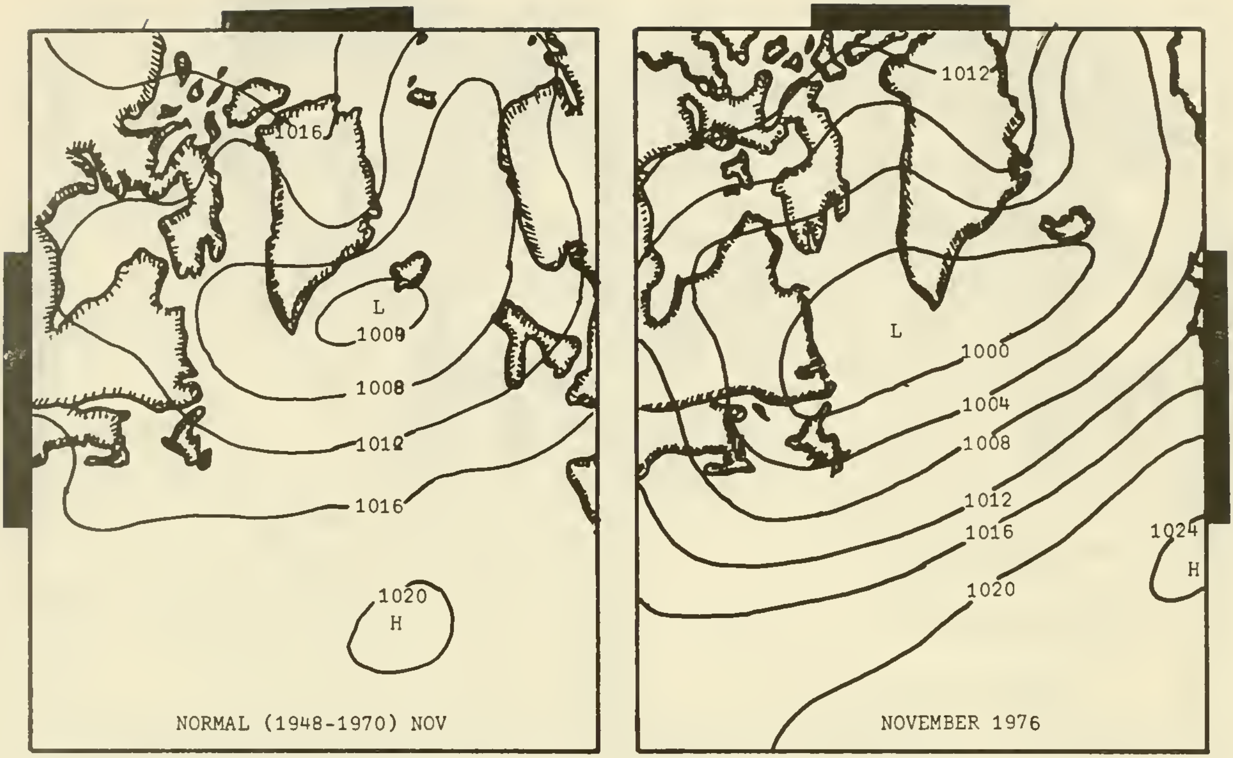


FIGURE 19c.—November 1976 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

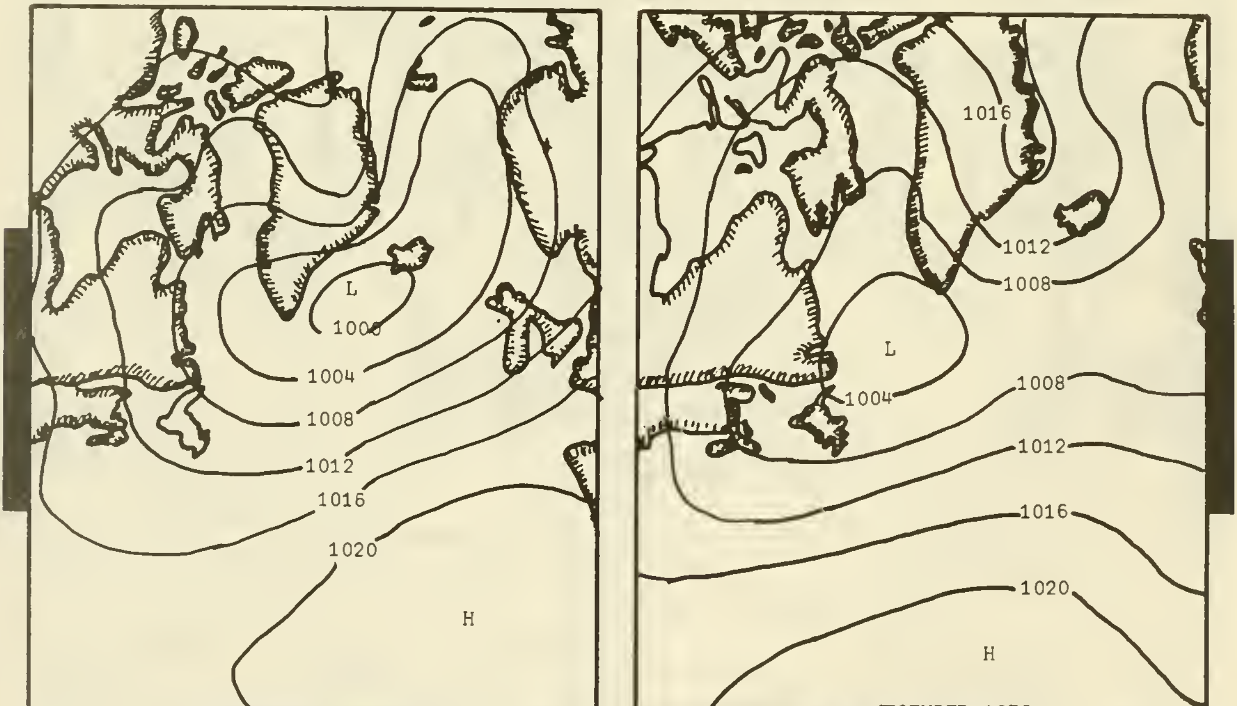


FIGURE 19d.—December 1976 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

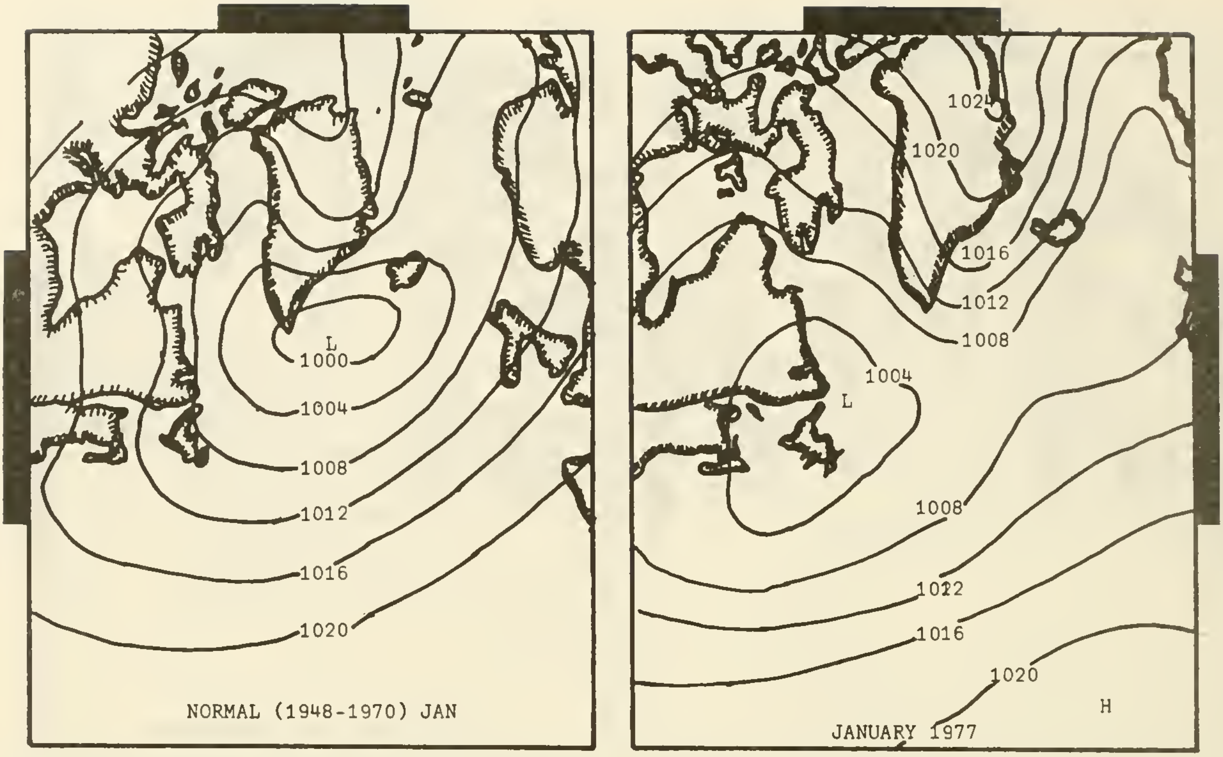


Figure 19e.—January 1977 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

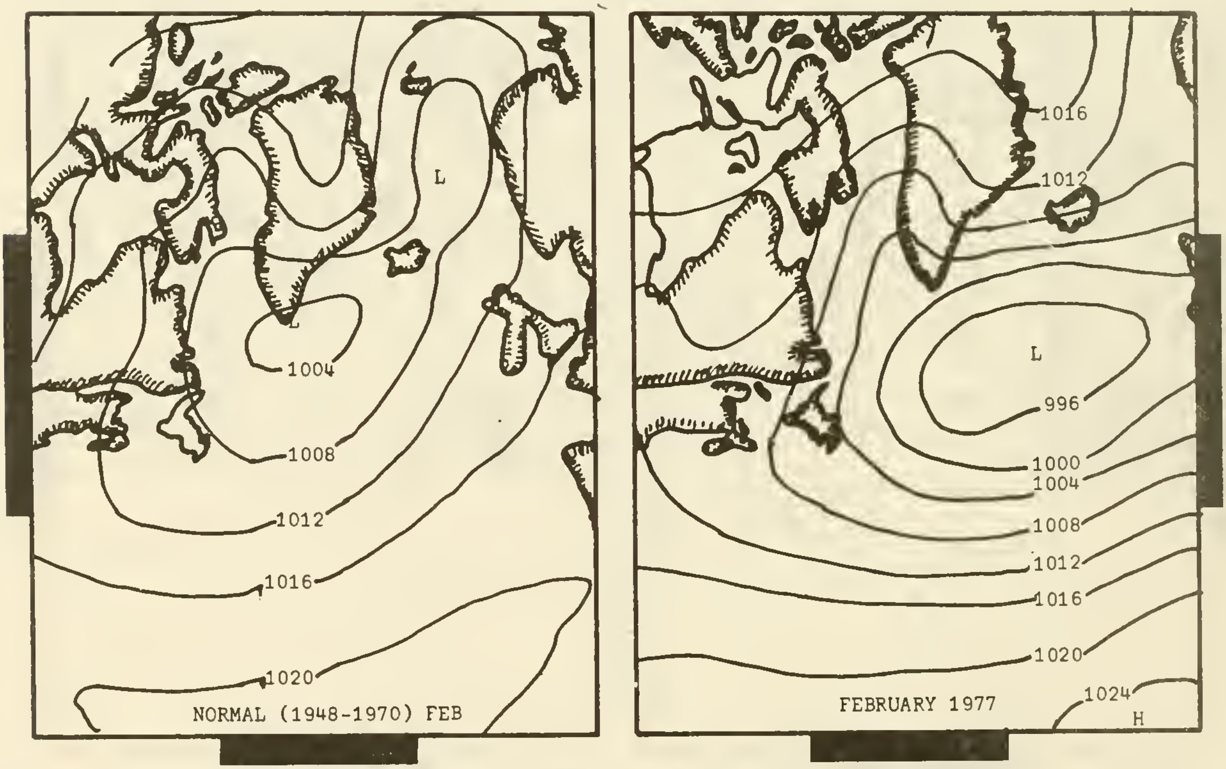


Figure 19f.—February 1977 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

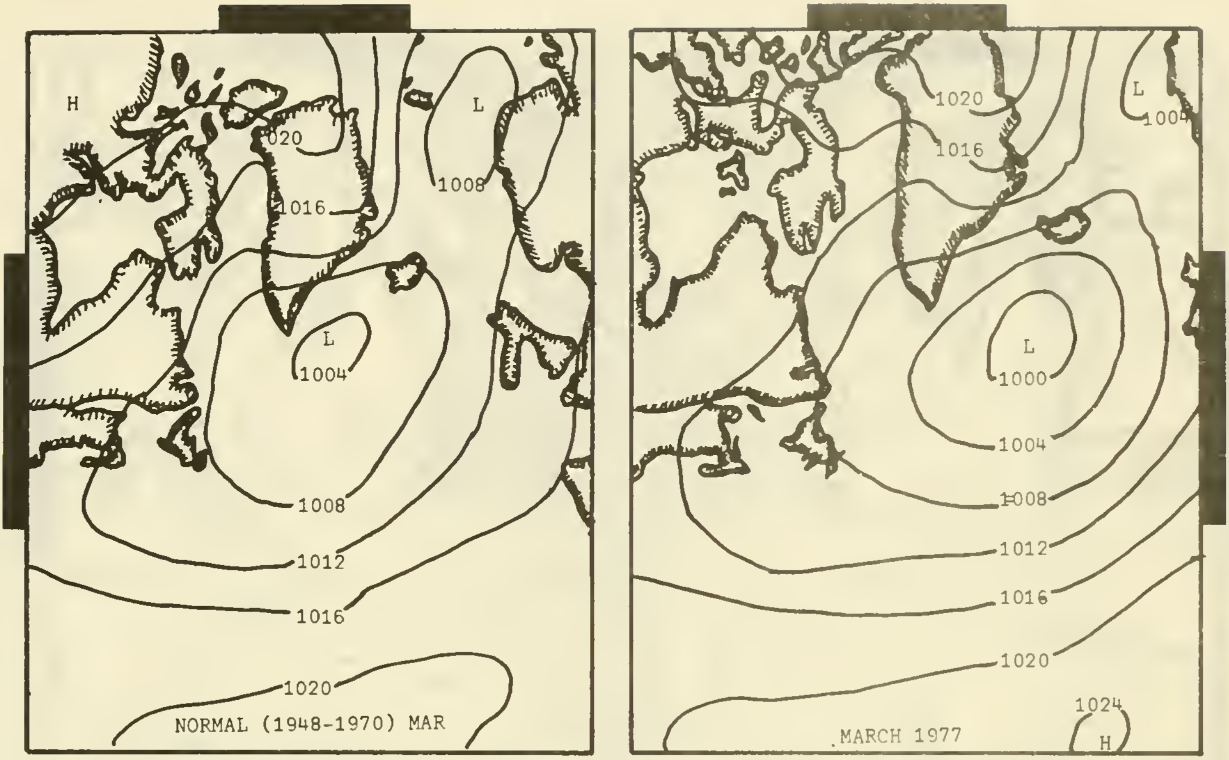


FIGURE 19g.—March 1977 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

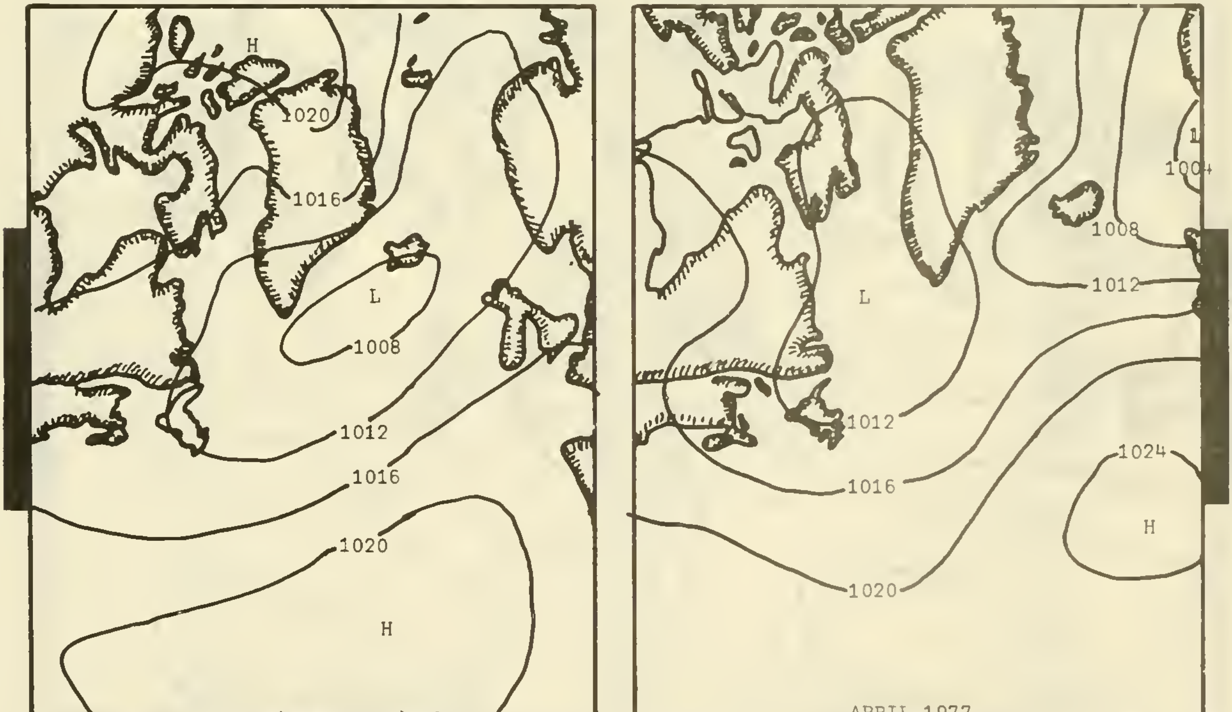


FIGURE 19h.—April 1977 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

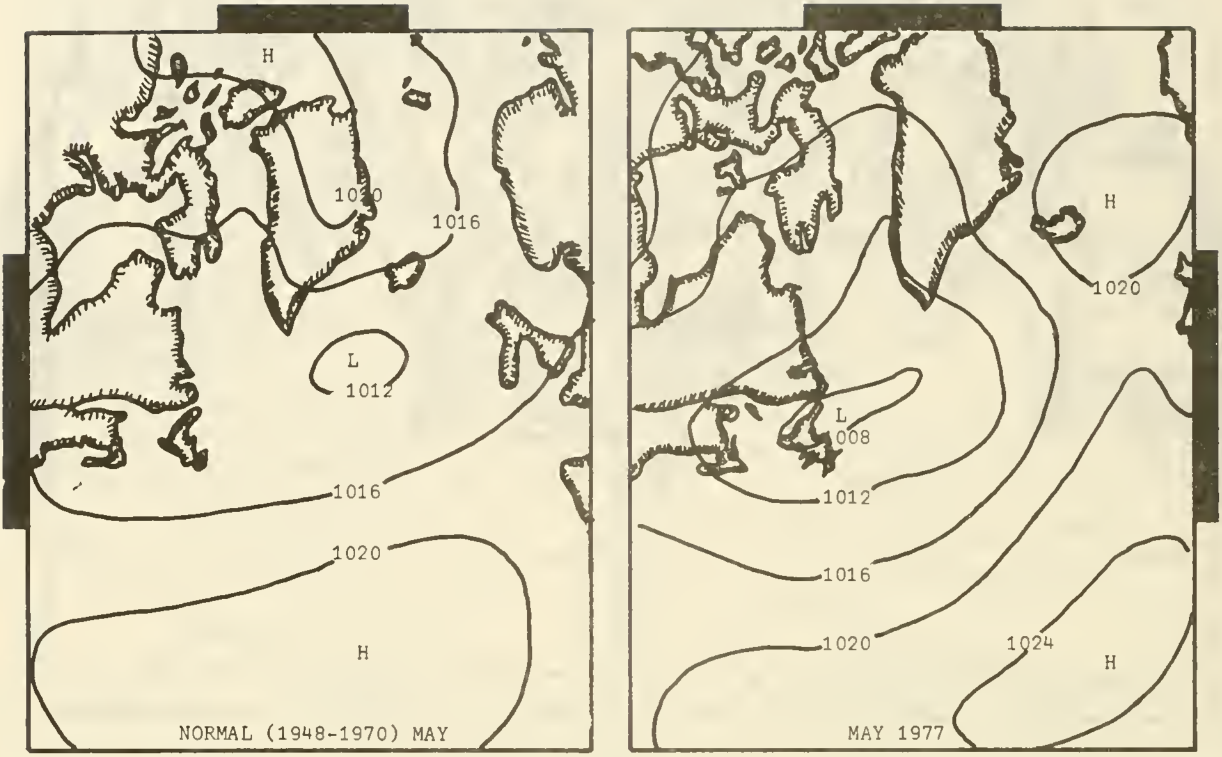


FIGURE 19i.—May 1977 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

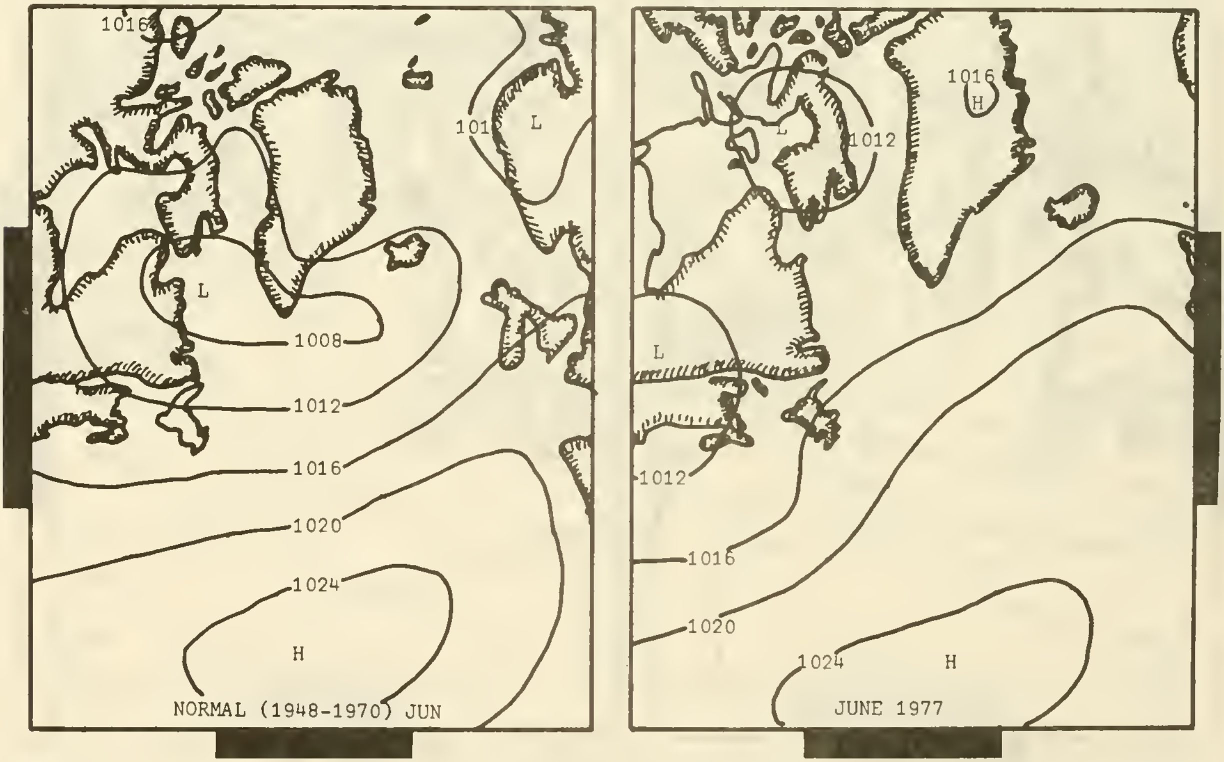


FIGURE 19j.—June 1977 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

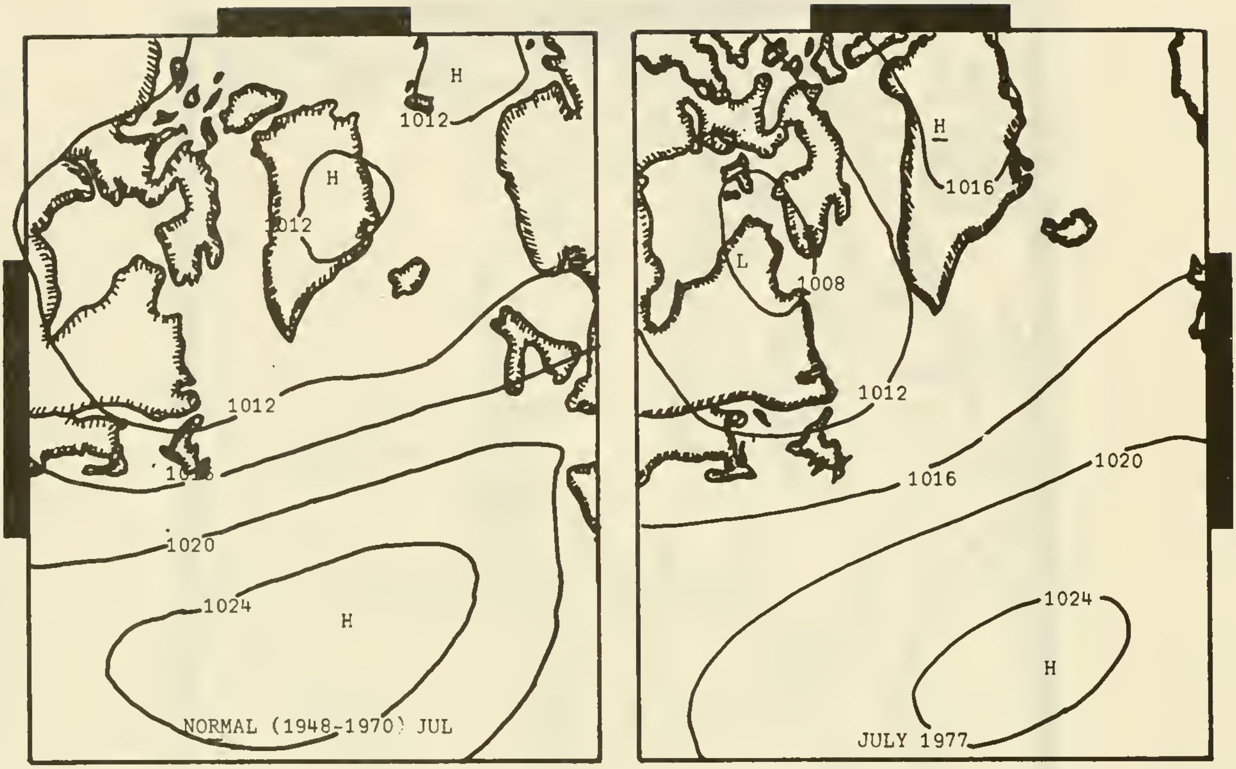


FIGURE 19k.—July 1977 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

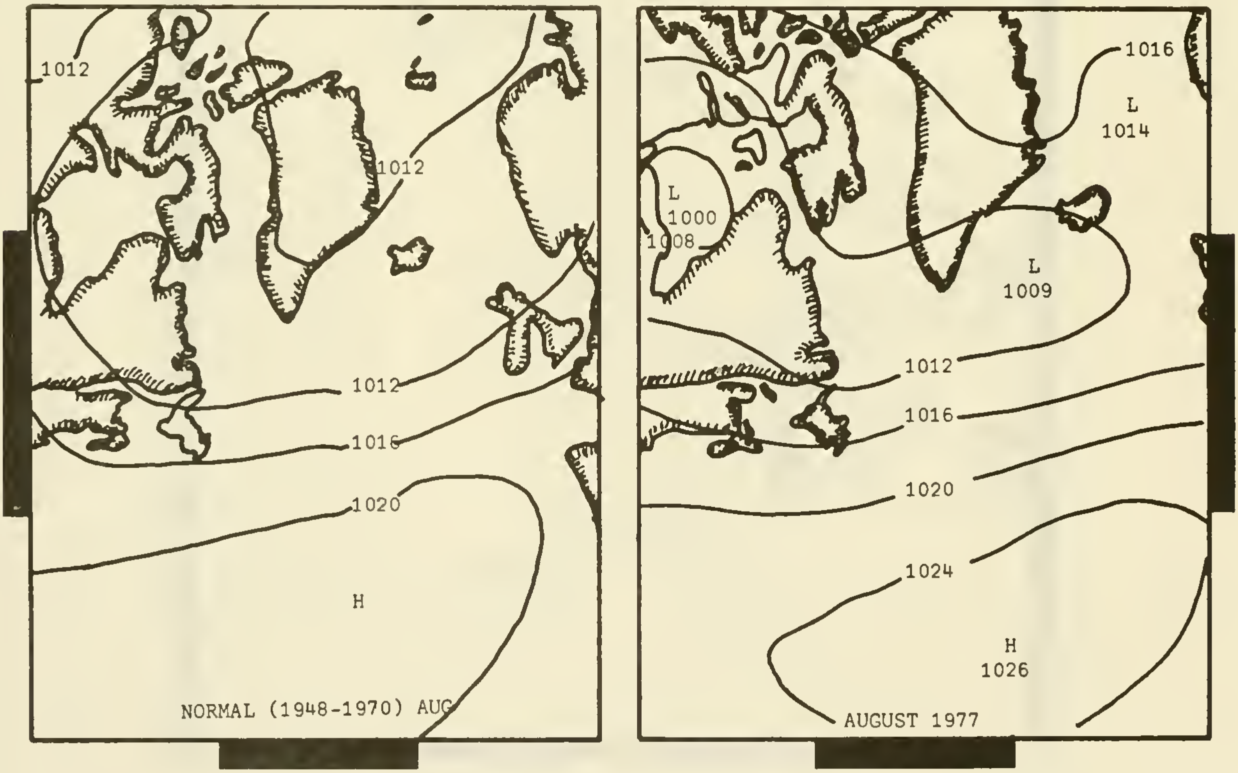


FIGURE 19l.—August 1977 Normal and Monthly Average Surface Pressure in mb Relative to 1000 mbs.

FIGURE 20.—Pressure Gradients Monitored by International Ice Patrol.

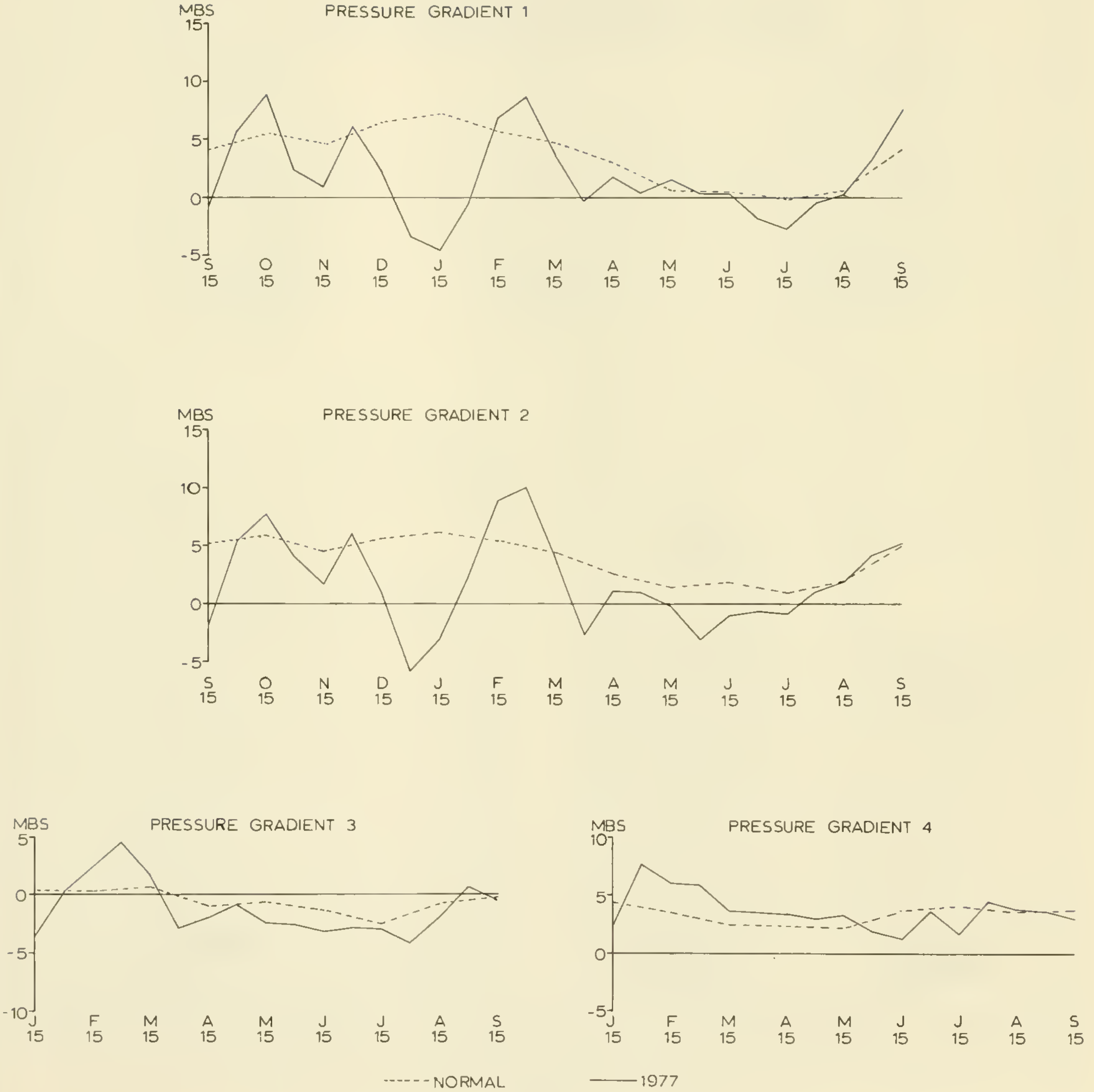


FIGURE 21.—PRESSURE GRADIENTS 1–4.

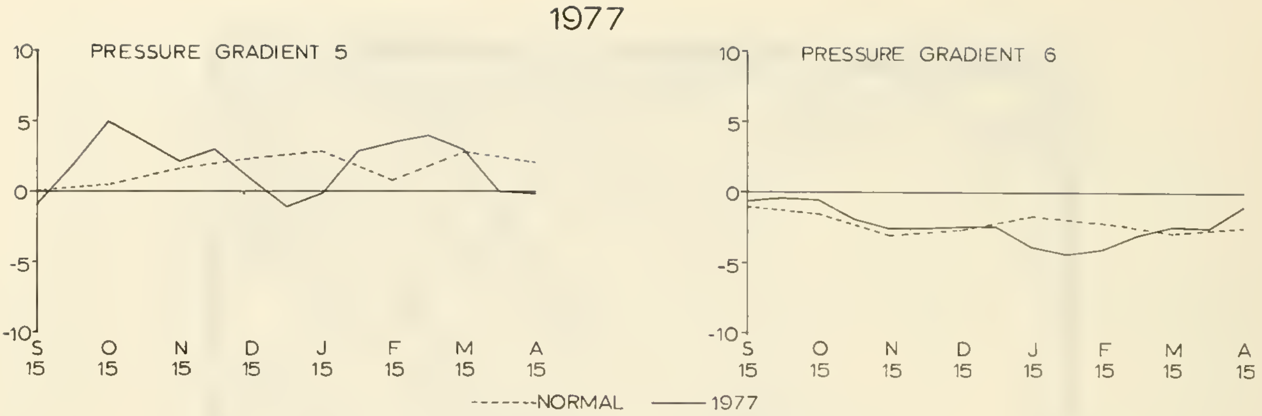


Figure 22.—PRESSURE GRADIENTS 5 and 6.

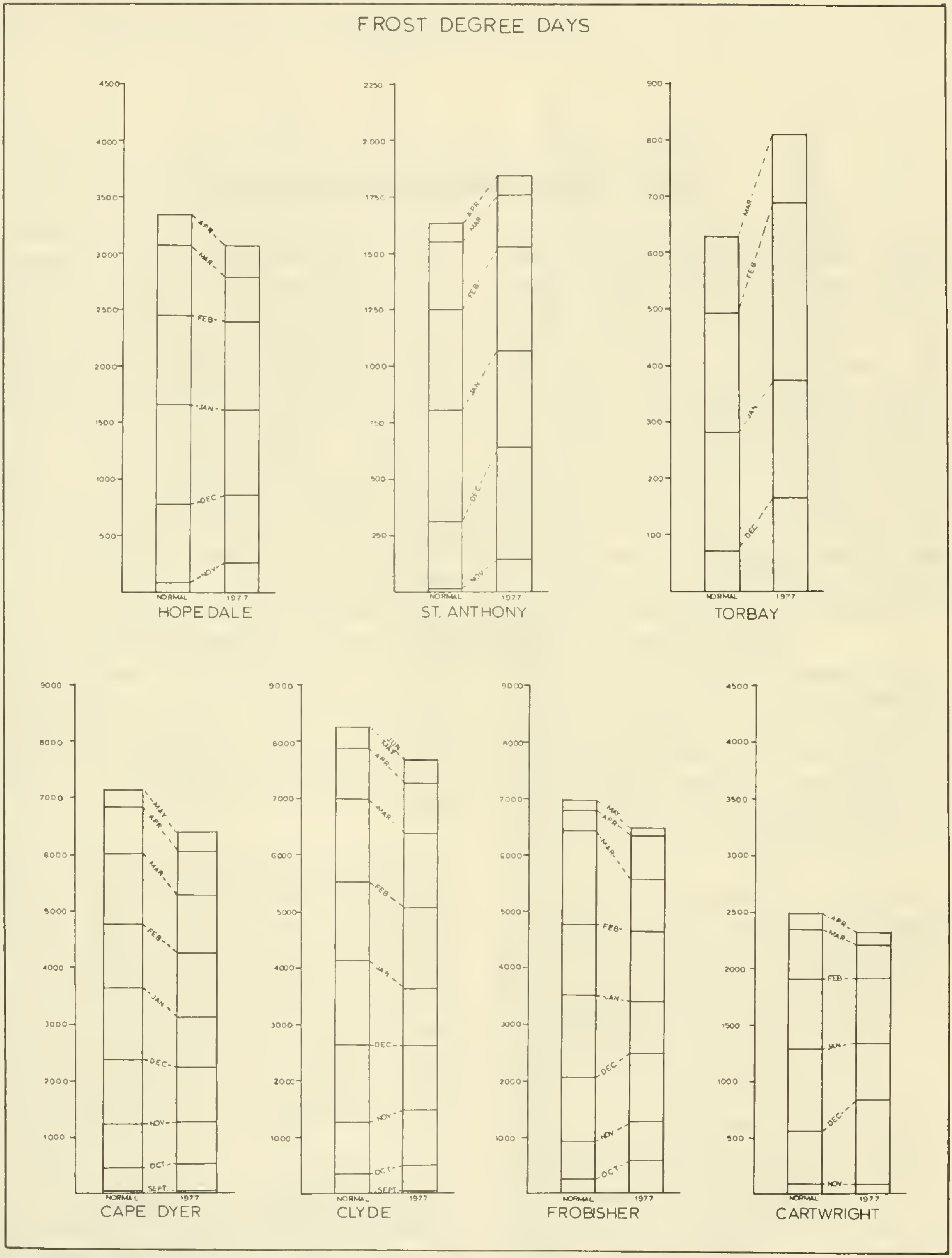


FIGURE 23.—Frost Degree Day Accumulations Calculated from Monthly Mean Fahrenheit Air Temperatures.

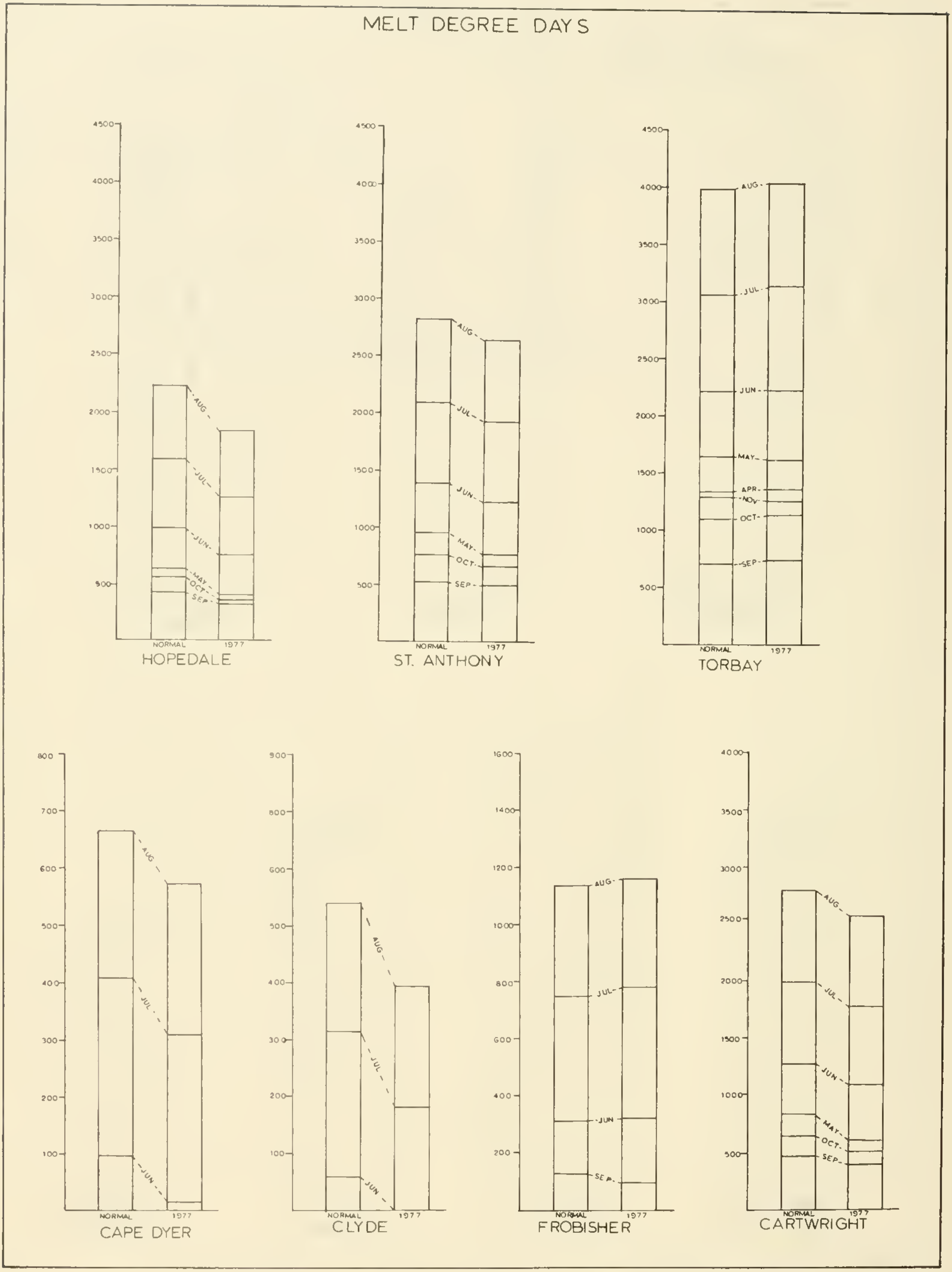


FIGURE 24.—Melt Degree Day Accumulations Calculated from Monthly Mean Fahrenheit Air Temperatures.

RESEARCH AND DEVELOPMENT—1977

During the 1977 Season, Ice Patrol continued the research and development program on remote sensing to provide an all-weather iceberg detection and identification tool. NASA Lewis Research Center provided a solid state Side-Looking Airborne Radar (SLAR), APS-94D model, which was installed in the Coast Guard HC-130B aircraft, CGNR 1351, used primarily on the Great Lakes ICEWARN project. Extensive SLAR data on icebergs and ships were accumulated during the season for use in bench testing for the Radar Image Processor (RIP) currently under development by NASA Lewis. The RIP, which shows promise for SLAR target discrimination, will undergo test and evaluation under operational conditions during the 1978 Ice Season.

The Airborne Oil Surveillance System (AOSS), newly installed in the Coast Guard HC-130B aircraft, CGNR 1347, was also tested during the 1977 Ice Season. This included evaluation of its APS-94D SLAR, Passive Microwave Imager (PMI), and ultraviolet/infrared line scanners.

Both the AOSS and ICEWARN SLAR systems show good potential for providing the all-weather iceberg detection and identification capability required to conduct effective and efficient surveillance. Development of effective methods for data interpretation through operator expertise and NASA Lewis' RIP should eventually eliminate the problem of dependence upon visual reconnaissance in Ice Patrol operating areas where fog and low cloud cover are so prevalent.

Satellite positioning buoys, such as the Buoy Transmit Terminal (BTT) and Air Deployable Remote Access Measurement System (ADRAMS) type, although barely past the test and evaluation stages themselves, have proven to be invaluable tools to Ice Patrol. The buoys continue to serve a variety of uses including location, speed, and direction of ocean currents, tagging of selected icebergs for drift studies, and improved season forecasting and prediction using data from buoys dropped on icebergs in the vicinity of Davis Strait or along the Labrador coast. Two ADRAMS were successfully deployed onto bergs on each side of Davis Strait during the February preseason flight. They functioned well and were tracked for more than four months, using the NIMBUS-6 satellite. The western leg was tracked all the way south to 51°N. More ADRAMS drops are planned for the 1978 season. The continued use of these buoys will greatly improve Ice Patrol operational effectiveness at relatively minimal cost.

This season also saw a continuation of the iceberg drift project. Using the integrating current drogue developed in 1976, a set of iceberg drift data was collected which included current, wind and iceberg velocities. Three sets of drifts were conducted, the first lasting 36 hours, the second 48 hours and the third a little over 24 hours.

In June, the test phase for the iceberg tethering dart was completed. This 35 pound anchoring projectile proved capable of penetrating 0.7 meters when dropped from 200 feet at 130 knots. It is planned to develop an expendable instrument package which will be attached to the tethering dart by means of a buoyant line. Appendix A gives details on this project.

The first remote sensing satellite devoted to oceanographic monitoring, SEASAT-A, will be launched during 1978. The International Ice Patrol and NASA Lewis have developed a joint plan for ground truthing and evaluation of SEASAT-A data applicable to the Ice Patrol mission. The RIP should be capable of interpreting the satellite's Synthetic Aperature Radar

(SAR) data. In this manner, simultaneous comparisons and evaluation of visual, SLAR, and SAR can be made. Ice Patrol aircraft and surface vessels will collect extensive visual and oceanographic data during routine operational missions for comparison with the SEASAT-A products. The SEASAT system has the potential of becoming the Ice Patrol's primary operational surveillance device by the mid-1980's should these first experiments prove successful.

Areas in which Ice Patrol research and development are directed remain unchanged, as can be noted in recent years. In order of priority, the primary problem areas are: (a) all-weather detection and identification of icebergs, (b) iceberg drift prediction, (c) iceberg deterioration. Although advances have been made during this past year in developing systems and devices to solve some of these problems, it is paramount that this vigorous research and development program continues.

ICE AND SEA SURFACE TEMPERATURE REPORTS RECEIVED FROM SHIPS OF PARTICIPATING NATIONS DURING 1977

BULGARIA	ICE	SST
FLAMINGO	1	
OLUSHA	1	
CANADA		
CAPE HARRISON	1	
HURON	2	39
SIR HUMPHREY	2	
CUBA		
RIO CANIMAR	1	
DENMARK		
ATLANTIC SKOU	1	
TORM ASLAUG	1	
EAST GERMANY		
ER MONTREAL	1	
GORLITZ		1
FINLAND		
GERMUNDOE	1	
FRANCE		
DELCHIM ALSACE		13
L'AGENAIS		8
GREAT BRITAIN		
ANCO TEMPLAR	1	
CAPULET		1
CRAMOND		3
CUNARD CHAMPION	2	
CUNARD CHIEFTAIN	2	
CP DISCOVERER	2	
CP TRADER	1	1
DORCASIA		5
EDEN FISHER	1	
E. W. BEATTY		1
FARNELLA		5
LA CHACRA		4
MANCHESTER CONCORDE	1	
VICTORE	1	
SUGAR REFINER	1	
W. C. VAN HORNE	1	
WAYFARER	1	

GREECE	ICE	SST
HELLAS IN ETERNITY		2
MARITSAPLEMOS	1	
GUADALUPE		
TOXOTIS		5
ICELAND		
BAKKAFOS		31
GODAFOSS	2	
SLAFTAFELL		7
SELFOSS	1	
INDIA		
JALABALA		1
ITALY		
MARE TIRRENO		1
LIBERIA		
BORDATXOA		1
CAPTAIN CARGILL		12
CARINA		2
HAMBURGER WAPPEN		6
HUNTER BOW	3	3
KATHLEEN	2	7
LORFRI		6
MELTEMI		3
UNIMAR	1	
NETHERLAND		
SMIT LLOYD	1	
NORWAY		
BAHMA		8
BERGE BONDE		8
BERGANDER	1	
BRUNHORN	1	
CORNER BROOK	1	
DYVI OCEANIC	1	
FROSTFJORD	1	
SANDVIKEN	1	1

PANAMA

CLAUDIA KOGEL		4
FIESTA		4
HARMONY		8
ROSEDAPHINE	1	
SEAFOX	1	

POLAND

PEGAZ	1	
FENIKS	1	

PAKISTAN

WARSAK		7

SINGAPORE

OCEAN INTREPID		2
TURICUM	1	

SWEDEN

ATLANTIC SPAN		11
BORELAND		7
JOH. GORTHON		1
MONT ROYAL	15	1

SWITZERLAND

SILVRETTA	1	

UNITED STATES OF AMERICA

ADMIRAL CALLAGHAN	1	1
AMERICAN ARGOSY	1	
LASH ITALIA		1
SEALIFT ARABIAN SEA	1	

UNITED STATES COAST GUARD

USCGC EVERGREEN	12	893
USCGC WESTWIND	3	

UNITED STATES NAVY

USN MIRFAK	1	

U.S.S.R.

KOMSMOLETS KUBANI	1	

WEST GERMANY

COLUMBUS VIRGINIA	1	
STADT WOLFBURG	13	15

YUGOSLAVIA

BANJA LUKA		5
DUBROBNIK		4

APPENDIX A

TAGGING OF ARCTIC ICEBERGS

by R. Q. ROBE and T. S. ELLIS
U.S. Coast Guard Research and Development Center

All of the early work with iceberg drift and deterioration considered the entire population of icebergs because of IIP's limited detection capability (Cheney, 1951). When icebergs were near the southern, western or eastern boundaries of the defined ice area, they were considered highly dangerous to shipping and a surface patrol vessel would be assigned to follow these bergs until they melted (Lenczyk, 1965). Only this continuous contact could assure that the iceberg being tracked remained the same piece of ice. Because of changes in the berg's shape by calving, rolling and melting, even repeated aircraft flights could not make positive identification in most cases (Lenczyk, 1965). During the 1960's, interest in predicting the behavior of individual icebergs increased for a number of reasons. First, IIP now had confidence that aircraft could spot and position bergs reliably over wide areas during periods of good weather. Since the lack of good weather has been a severe problem, a means to predict the position between sightings is needed. Second, even with accurate drift prediction, the berg's rate of deterioration must be estimated so that it will not be carried on the ice plot for much more than a day after it has melted, or worse, be eliminated from the ice plot prior to melting.

Answers to questions of drift and deterioration prediction require that many individual icebergs be studied over an extended period of time. These studies require that the researcher be certain he is working with the same bergs and not other icebergs in the same area. Early identification attempts made use of dye to color the sides of the berg. Kollmeyer (1966) used test tubes filled with various dyes and shot them on an arrow from a bow to mark a position on the face of an iceberg. This mark was used as a reference during a deterioration study. Over the years, IIP aircraft have repeatedly "bombed" bergs with dye to aid in their identification. This has limited utility because rolling and melting of the iceberg soon washes the color away. Dye has a life of one to two days depending on weather conditions and melting and rolling of the ice.

In 1974, the Coast Guard Oceanographic Unit began a project to determine the best way to tag an iceberg for identification and relocation. The first approach was to encircle a berg with a floating line (Hayes et al., 1975). The 0.95 cm line made of polypropylene was provided with additional floatation along its length (Figure A–1). Radar reflectors and a Radio Direction Finder transmitter were included as elements in the line.

Two tagging attempts were made using this method. On the first, three bergs were tagged. The arrays were carried away in a storm and only one was recovered. The line on the recovered array was broken in two places. One break occurred with such force that the ends of the fibers were fused. There was no evidence of chafing. The other break appeared to be the result of chafing. The second attempt had quite different results. Weather was fairly calm and several bergs were tracked in dense fog for nine days. However, the tagging arrays slipped repeatedly over or under the bergs. This necessitated early recovery of the equipment which drifted away from the iceberg, although the line circle remained intact. This result was completely unexpected and probably was caused by the berg snagging the line and rolling out of the loop (Hayes et al., 1975). It should be remembered that these icebergs were in an advanced stage of deterioration and quite likely to roll.

A similar experiment was carried out in 1976 (Brooks, 1977). After consultation with the

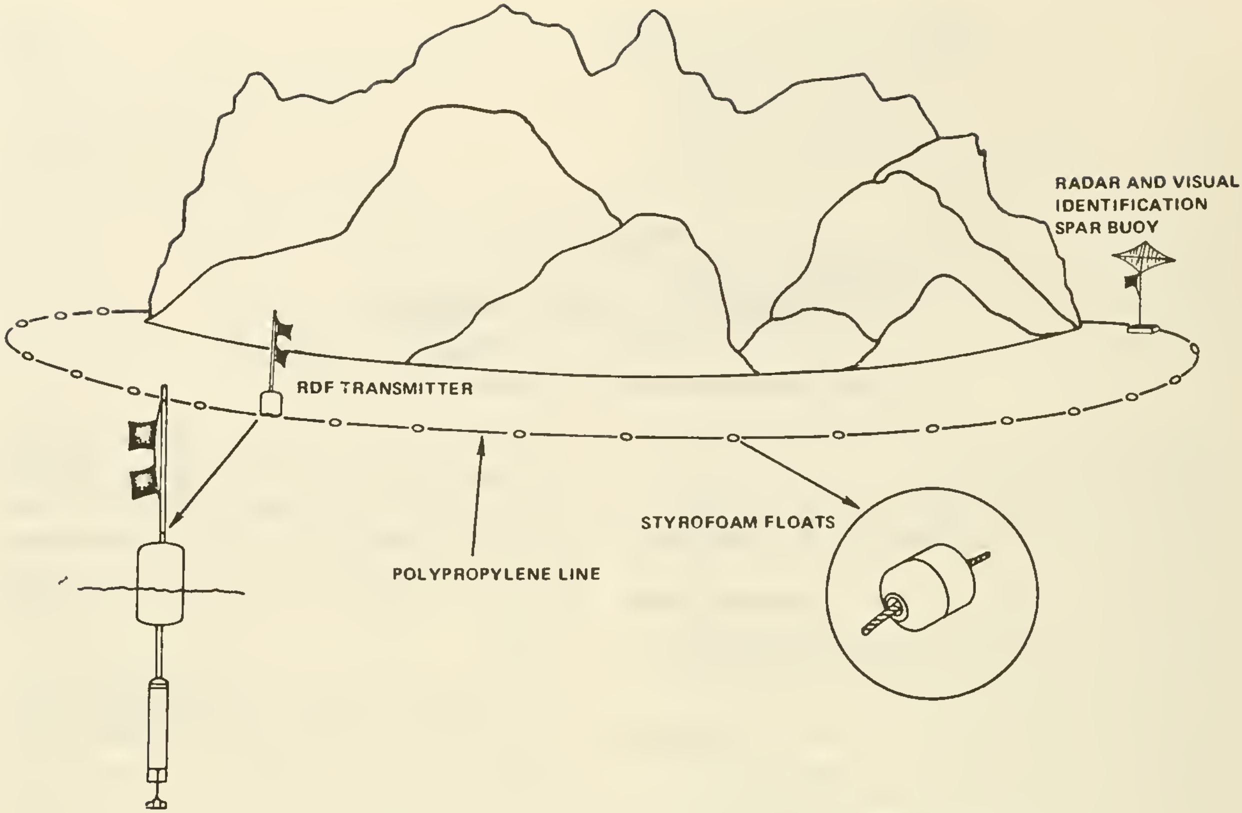


FIGURE A–1.—An Iceberg Tagging Scheme Using a Floating-Line Technique.

Coast Guard, he used a much heavier line (24mm polypropylene). Since the experiment was conducted at nearly 60°N, the icebergs could be expected to be more stable. The array was tracked using the NIMBUS–6 satellite system, but no attempt was made to verify whether the iceberg remained with the transmitter. The transmitter was not recovered.

The development of an instrument package which can be attached to an iceberg requires solutions to three problems; rolling, melting and calving. In 1975, the Coast Guard Research and Development Center tried a new approach to tethering an instrument package to a berg by using a large steel dart with a trailing line which attached to a floating instrument package. This solves the problem of rolling and melting, but not calving. It is not likely that any system can survive calving, since the anchoring piece of ice would drift away rapidly from the iceberg itself, or any conceivable line would be parted by the weight of several hundred tons of ice falling from the side of the berg.

The dart was designed by applying the relatively new branch of dynamics called terra-dynamics, which is the study of the forces acting on a body in relative motion to solid materials. After several trials, which included about two dozen drops, the present design was arrived at. The requirements were that it be easy to ship and assemble, cheap to build, and have stability and penetration for low altitude drops. The dart was manufactured from 5.72 cm cold rolled steel and 2.54 cm steel rod (Figures T–2 and A–3). It weighs 13.64 kg and has a 46 cm tail assembly of extruded high density polyethylene (Figure A–4).

Using the equations developed by Young (1972), it was possible to calculate the approximate depth of penetration of a steel dart in glacial ice. The empirical equation was:

$$D=0.0117\ K\ S\ N\ \sqrt{W/A}\ (V-30.48)$$

for impact velocities greater than 61 m/s. Where:

D = Depth of penetration, m
K = Scale factor, dimensionless
S = Index of penetrability, dimensionless
N = Nose performance coefficient, dimensionless
W = Dart weight, kg
A = Cross sectional area, cm^2
V = Impact velocity, m/s

The dart was attached to 300 meters of floatable polypropylene line with a small section of cable to reduce chafing. For a drop from 60 to 90 meters altitude, with this length the line is still leaving the aircraft after the dart has hit. This results in the line laying smoothly on the surface and with little or no pull on the instrument package. The instruments can then be allowed to free-fall or be lowered by parachute.

The line was originally placed on a faking board similar to those used with a Lyle lifesaving gun in the late 19th and early 20th centuries (Figure A–5) (Lyle, 1878). The board was mounted vertically on the lowered rear ramp of a C–130 aircraft in flight. Over 300 meters of line feed off the board in less than five seconds. Stress problems developed with the board concept when the bottom layers were reached. A much improved method of deploying the line was developed by Farmer (1977) (Figure A–6). The line was packed in bundles secured by rubber bands. All of the bundles were then placed in a parachute pack which was opened when the dart was thrown from the rear ramp of the C–130, thereby allowing the bundles to smoothly unravel one at a time. The instruments can then be launched just before the last of the bundles unravel.

A final instrument package has not been developed for the tagging system. In tests, we have used a modified sonobuoy as an expendable transmitter.

In addition to ten test drops on icebergs in 1975 and 1977, several tests of the system have been conducted over land at the Coast Guard Elizabeth City Air Station. Drops were made from 61 meters at an airspeed of 130 knots (67 m/s) and ice was assumed to have an index of penetrability of 2.5. The 1975 test gave a penetration of 1.1 meters and the 1977 test (Figure A–7) had a penetration of 0.76 meters. Other penetrations of the iceberg were not accessible from a small boat or were under water. Results are as follows:

(a) *Accuracy*—After several practice runs, pilots can hit an iceberg as small as 20 meters on a side 75 percent of the time from 61 or 91 meters altitude.

(b) *Line Handling*—The parachute pack line handling system developed by Farmer does a superior job of deploying large quantities of line without kinks or tangles.

(c) *Penetration*—The dart which was used in the tests on icebergs in 1975 and 1977 had a predicted penetration characteristic as given in Table 1 (Young, 1972).

(d) *Holding Strength*—The holding power of the 1977 test with 0.76 meter penetration exceeded the strength of a 1.25 cm polypropylene line which is approximately 5,000 pounds.

Further development of an expendable instrument package is planned, permitting the tracking of icebergs both from the surface and from satellite.

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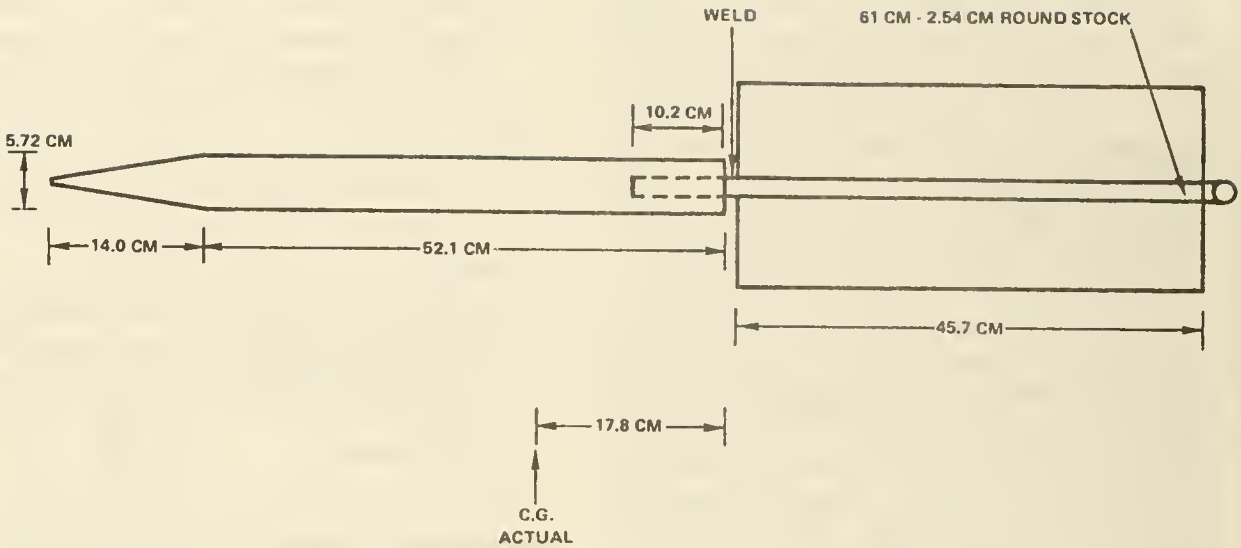

FIGURE A-2.—Iceberg Tethering Dart.

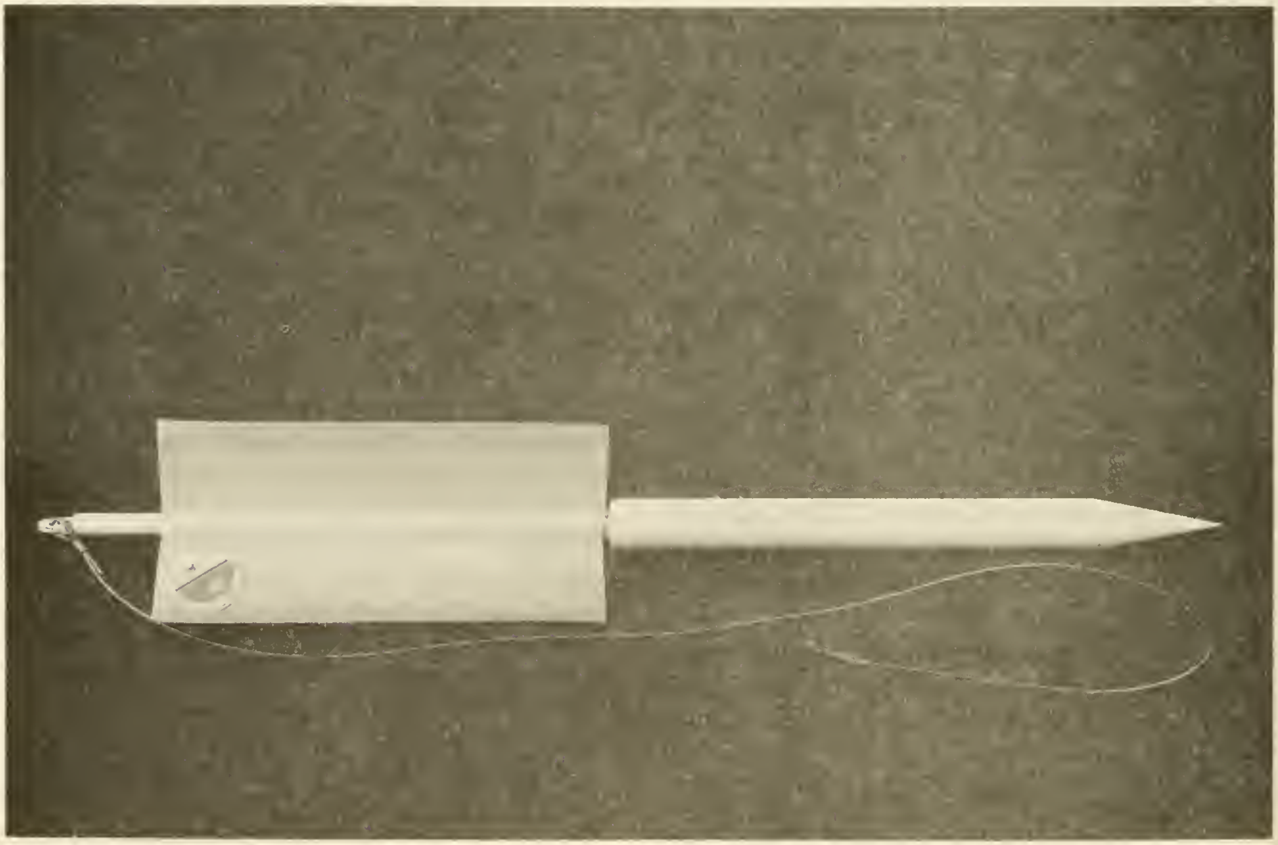

FIGURE A-3.—Iceberg Tethering Dart.

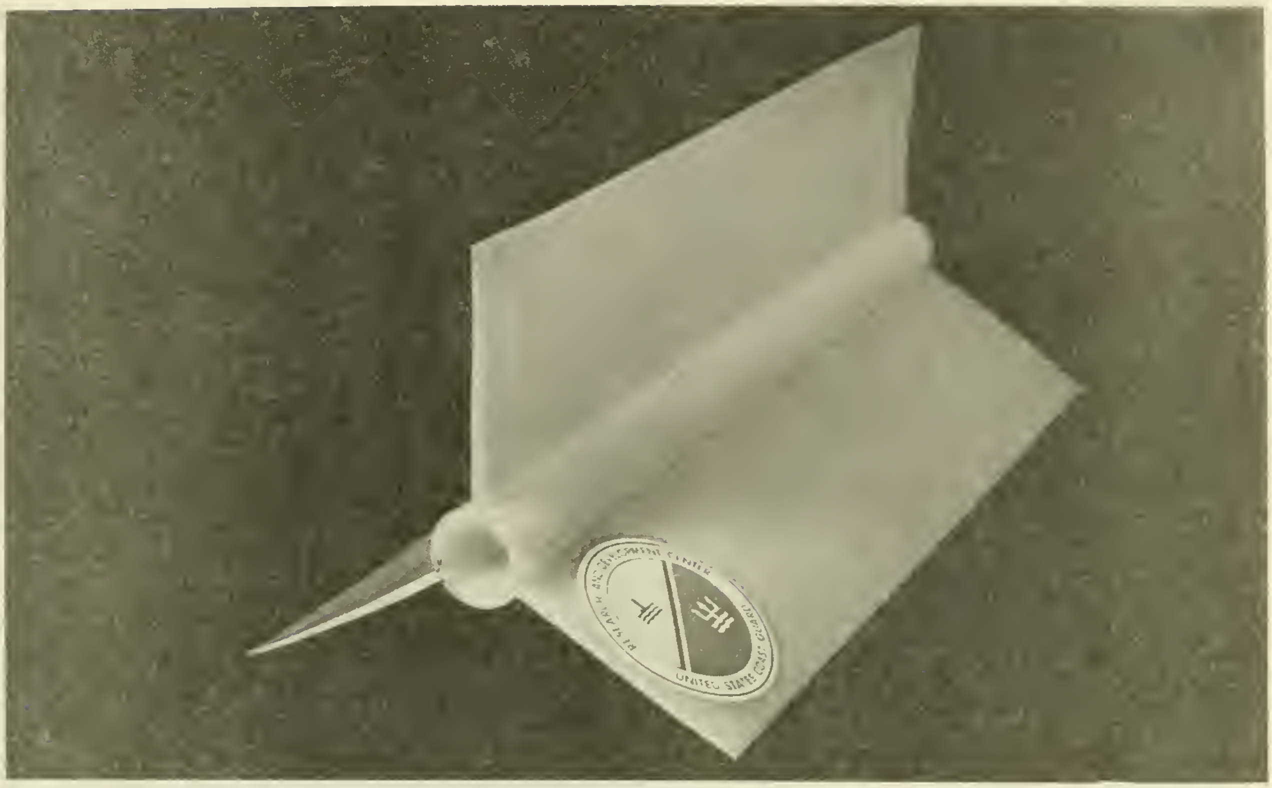

FIGURE A-4.—The Four Piece Extruded Iceberg—Tethering Dart Tail Assembly.

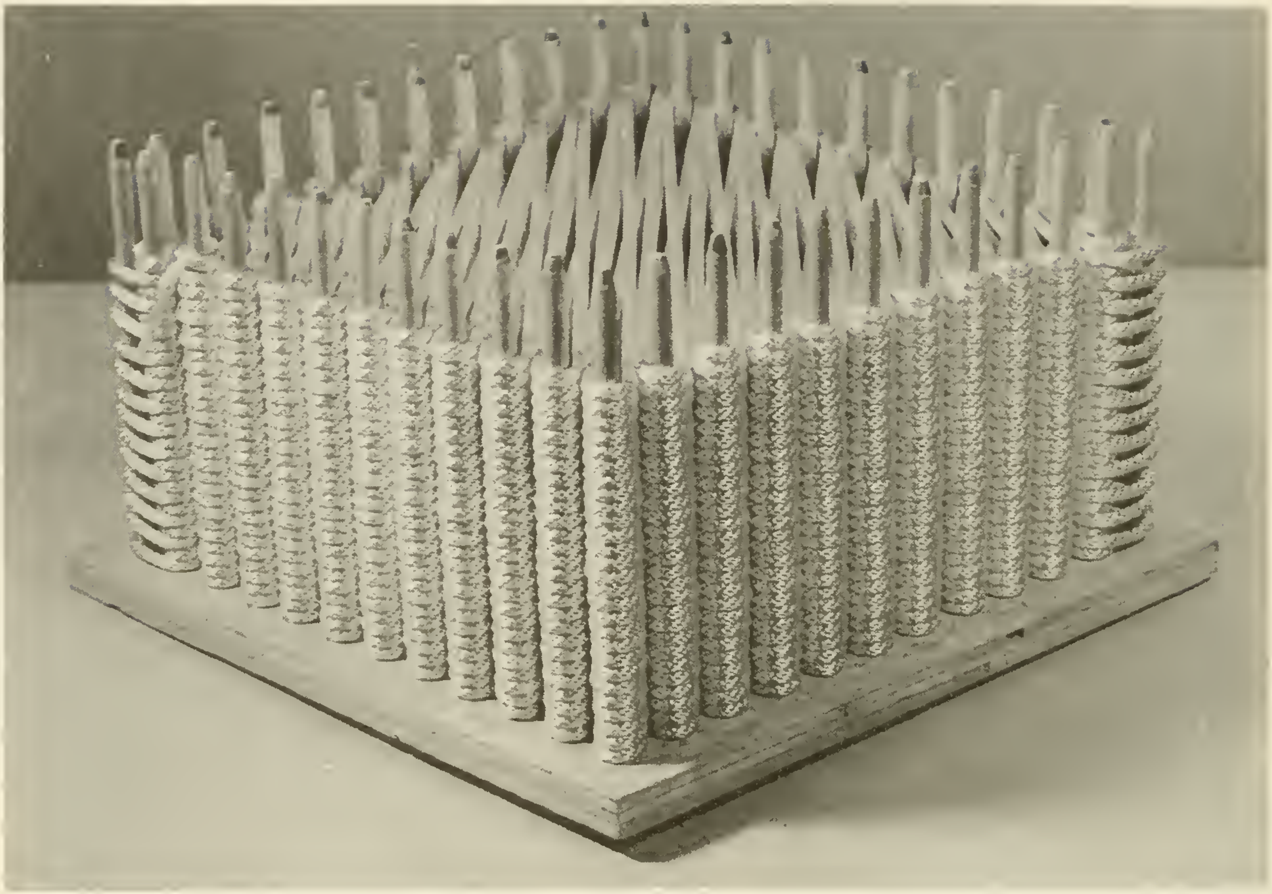

FIGURE A-5.—Line Faking Board.

Figure A–6.—Trailing Line Pack.

FIGURE A-7.—Iceberg Tethering Dart in the side of an Iceberg, 1975 Tests.

APPENDIX B

LABRADOR CURRENT COMPUTER MODEL

A report on completion of size expansion and suggested operational implementation

by Captain Ronald C. Kollmeyer, Ph.D., USCG

A hydrodynamic numerical predictive computer model of the Labrador Current off the Grand Banks of Newfoundland was completed and tested against collected data in 1974. This model had 4 layers with an area of one degree square of latitude. The region modeled was located at 43°51′N, 49°20′W. This model was further tested in June 1975. For these tests, the model successfully predicted the current induced environmental changes in temperature and salinity distribution for an eight day period.

Further work has been completed on the model (January-July 1977) in the form of larger area coverage, two degree square of latitude, and an increase to six layers. In addition, the model has been made ready for operational testing and use by International Ice Patrol by development of a data handling system that allows direct input of the vertical distribution of temperature and salinity from hydrographic casts. This work is reported on herein.

Successful predictions through model operation depend on the quantity of the collected input data points together with the degree of synopticity. The more closely spaced the hydrographic casts are in both space and time, the more correct will be the output results. For the newly developed larger area model, data collection from a surface vessel in the traditional manner (STD casts) is not sufficiently fast to provide for either the desired sampling density or the required synopticity. It is expected that eventual development by the Navy (NORDA, Bay St. Louis, Miss.) of the air deployable, expendable salinity/temperature/depth sensors will provide the suitable data suite required by the model. Prototype sensing probes are expected to be available by 1980/81 and possibly earlier.

The model predicts currents relative to the 1000 decibar isobaric surface (approximately 1000 meters depth). This isobaric level has been used for current calculations by IIP for the past 50 years. Evidence exists that the 1000 decibar level is itself in motion, and thus knowledge of this motion is needed as a model input to provide for absolute motion drift prediction. Data concerning the sea surface slope in the modeled area would provide the necessary information on which the model could base these absolute motion calculations. Eventually, the SEASAT B satellite may give us that information to the acceptable accuracy of 1 centimeter of elevation per 1 kilometer in the horizontal.

The Labrador Current Model now covers any selected area of the Grand Banks of Newfoundland. The model size compared to the overall problem area is shown in Figure B–1. The coverage is 120 x 120 nautical miles. There are six layers in the model, with thickness of 30, 40, 80, 150, 200 and 500 meters. The model is initiated by introducing a processed data set which is the output of a newly developed data handling program described in later paragraphs. This data set consists of 24,300 layer averaged temperature and salinity data points, 2025 points describing the bathymetry of the area modeled, the wind field (both present and expected during the model's predictive period), the position of the southwesternmost corner of the area modeled, and the commencement time of the predictive period. Upon commencement of model operation, the initial conditions of the current field are calculated and then recalculated each hour as time advances. The recalculations are based on the advection (movement) of the water and the mixing (interaction). These provide the steering mechanism that alters both the velocity and

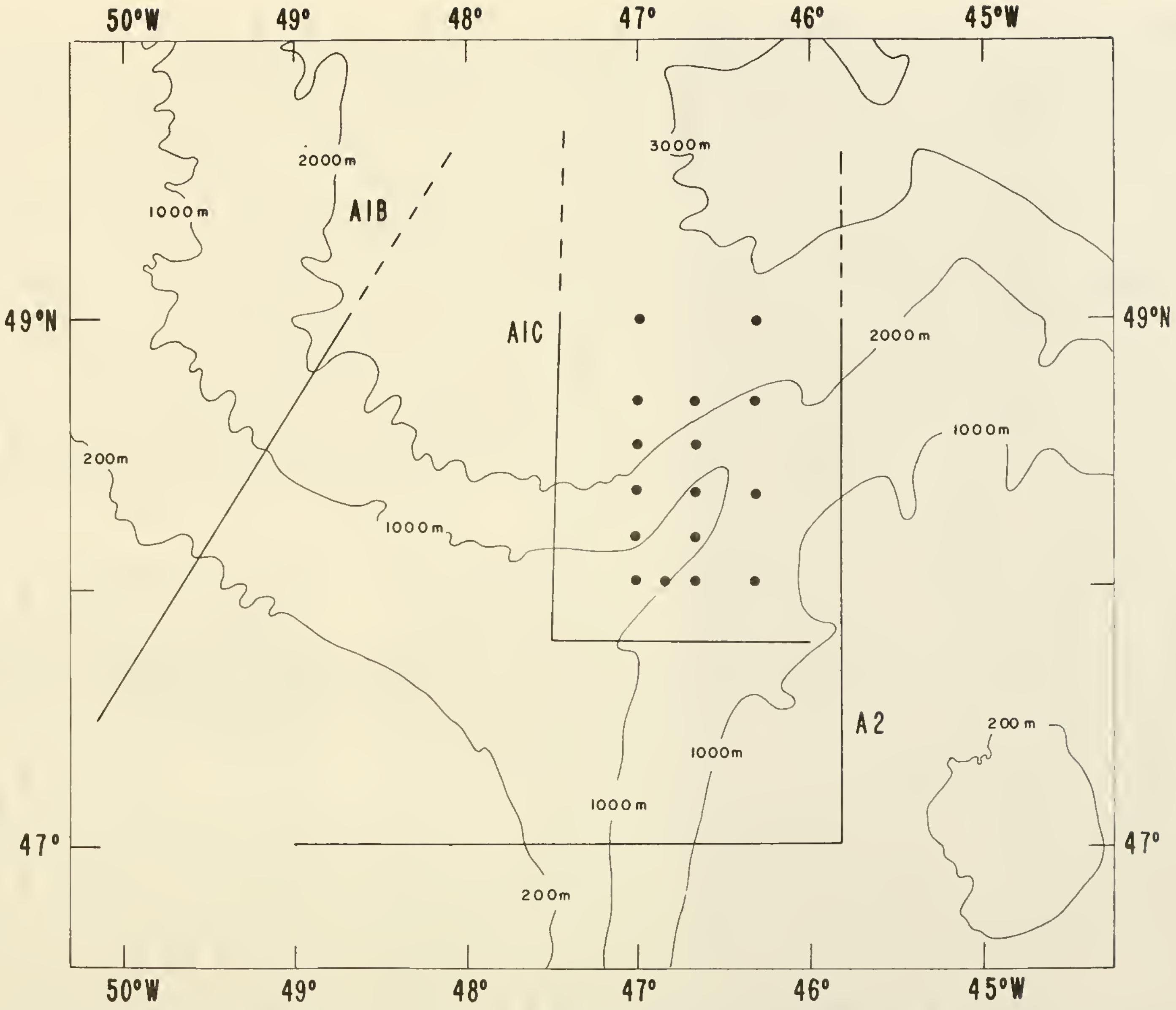

Figure B–1.—The area of primary concern to International Ice Patrol. Solid straight lines indicate Ice Patrol Standard Sections. Solid circles depict survey stations covering an area of the size used by the Labrador Current Model.

```
Southwest corner of model grid is 4351 N. Lat, 4920 W. Long
Prediction starts; MONTH   5  DAY  20  HR   1800  YR    1980
Time step = 3600.SEC   Grid size is 5 KM.
Layer No.    Layer Depths      Lateral Friction    Diffusion Coef.    Vertical Friction
    1          0 - 70 M.           0.3E 07            0.5E 05              0.005
    2         30 - 70 M.           0.3E 07            0.5E 05              0.005
    3         70 - 150 M.          0.1E 07            0.3E 05              0.005
    4        150 - 300 M.          0.1E 07            0.1E 04              0.005
    5        300 - 500 M.          0.1E 07            0.1E 03              0.005
    6        500 - 1000 M.         0.1E 07            0.1E 03              0.005
Vertical Friction Along Bottom/Water Interface is 0.010
```

FIGURE B–2.—Computer Output Heading of the Labrador Current Model.

direction of the current systems with time. Hourly current predictions are available and the model can be instructed as to the frequency of output desired. The output consists of the U and V vector velocities, temperature, and salinity distributions for each layer of the model. In addition, the density distribution of the layers may also be called out if desired. The initial heading of the model output lists such facts as the location of the area modeled, month/day/hour and year of the start of the predictive period, the time step, grid size and the various coefficients used by the model as shown in Figure B–2.

The model is presently being run on an IBM 360/370 computer at the University of Connecticut, Storrs, CT. A 10 day predictive run takes 608,000 words of core memory and will use approximately 95 minutes of Central Processor Unit (CPU) time.

An increase in predictive accuracy of the program can be realized through the boundary monitoring of the modeled area at certain critical locations. Additional data sampling across the Labrador Current and the Gulf Stream where they enter the modeled area will allow for increases in both predictive accuracy and length of prediction. The monitoring of boundaries, if done by air deployable probes every 8 to 10 days, could allow a probable predictive period of up to a month before re-initiation is necessary. The original one degree square model was tested successfully for up to eight days. This expanded model has not been tested against real data, so the length of the predictive period is only speculative at this time.

An extensive data handling system has been developed to speed the preparation of the data into a form which is directly usable by the model. For any given data collection survey, the region to be modeled is selected and the temperature/salinity/depth data are gathered throughout the region using some form of a continuous vertical sampling instrument. Data will generally be in the form of magnetic or punched tapes which contain individual station information. This includes the station number, latitude and longitude, water depth and the serial depth/temperature/salinity distributions. After some degree of quality control, generally in the form of either eyeball analysis or computer processing, a data set is produced. This data set may list depth/temperature/salinity distributions spaced as close

as one meter from the surface to the bottom of the hydrographic cast. This quality controlled data set forms the input to the Data Processing Program which prepares the data for use by the Labrador Current Model.

Input data must be in the form of temperature and salinity vertical averages for each of the six model layers. In addition, these averaged values must also be located at each grid point of the model matrix (2025 grid points). The Data Processing Program takes the sampled data, positioned by latitude and longitude, calculates averages for the six layers at the sampled stations, locates these averages in the matrix grid system and proceeds to scale the data at all grid points based solely on those locations sampled and the bottom bathmetry. The program is constructed so that if only two sampled data points existed in any layer, a complete data field would be generated based on those two points. Obviously, the more sampled data, the more accurate will be the scaled data field. The scaling program uses a system developed by several Coast Guard Academy cadets and myself while working on 1975 model tests. This routine iterates for a maximum of 150 cycles or until the temperature and/or salinity data ceases to change by more than .01. The number of iterations used is printed out for both temperature and salinity and for each layer for quality control.

When the sampled data are initially entered into the Data Processing Program, the location of the area to be modeled is also entered. The sampled data locations are checked and are discarded if they lie more than 5 km outside the desired model area. The program gives as a printout; model location, a list of stations used showing their number, grid location, and latitude and longitude. Following this output is the bathymetric data for the area modeled. The next series of outputs is supplied sequentially for each layer: the base matrix indicating the intersection of the continental shelf or the location of open boundaries; location and value of the sampled temperature averaged over the layer followed by a similar one for salinity; the number of iterations used to complete the scaling process; the properly formated data for model input (first temperature then salinity); and lastly a complete temperature and salinity data matrix for that layer which can be quickly scanned or contoured for quality control. The program is presently being run on a UNIVAC 1108 at the Underwater Systems Center, New London, CT. It requires less than 50,000 words of core memory and can be run in less than 15 minutes of CPU time.

A complete system for determination and prediction of the Labrador Current is envisioned as a future goal. This would include the air deployable expendable conductivity-temperature-depth probes under development by the Navy. These instruments could supply sufficient data from the area to be modeled in a timely manner. A peripheral quality control program could ready this raw data for input into the primary Data Processing Program, which could have available to it as a data bank, the complete bathymetry of the Grand Banks region and upon command select the proper bathymetric input for the desired model location. This data program would then produce a complete data set for input into the main model program. At this same time, present and predicted winds would be entered along with satellite information concerning the slope of the sea surface. The model could then produce predictions of the absolute current system which would be valid for up to 10 days, i.e., flights updating data of the boundaries where the Labrador and the Gulf Stream enter the model would be required for extended predictions. These would consist of short flights using the air deployable data probes to check on the location, salinity and temperatures of the major currents entering the modeled area. A summary of this IIP Labrador Current Determination System is shown in Figure B–3. The shaded area reflects the work which has already been accomplished. Completion of the other parts of the system must wait for the technology to develop. However, the bathymetric data bank for the entire region could be prepared at this time to facilitate present use of the model as a substitute for the Dynamic Height method used by IIP.

Further model development possibilities have emerged in the form of vorticity modeling work

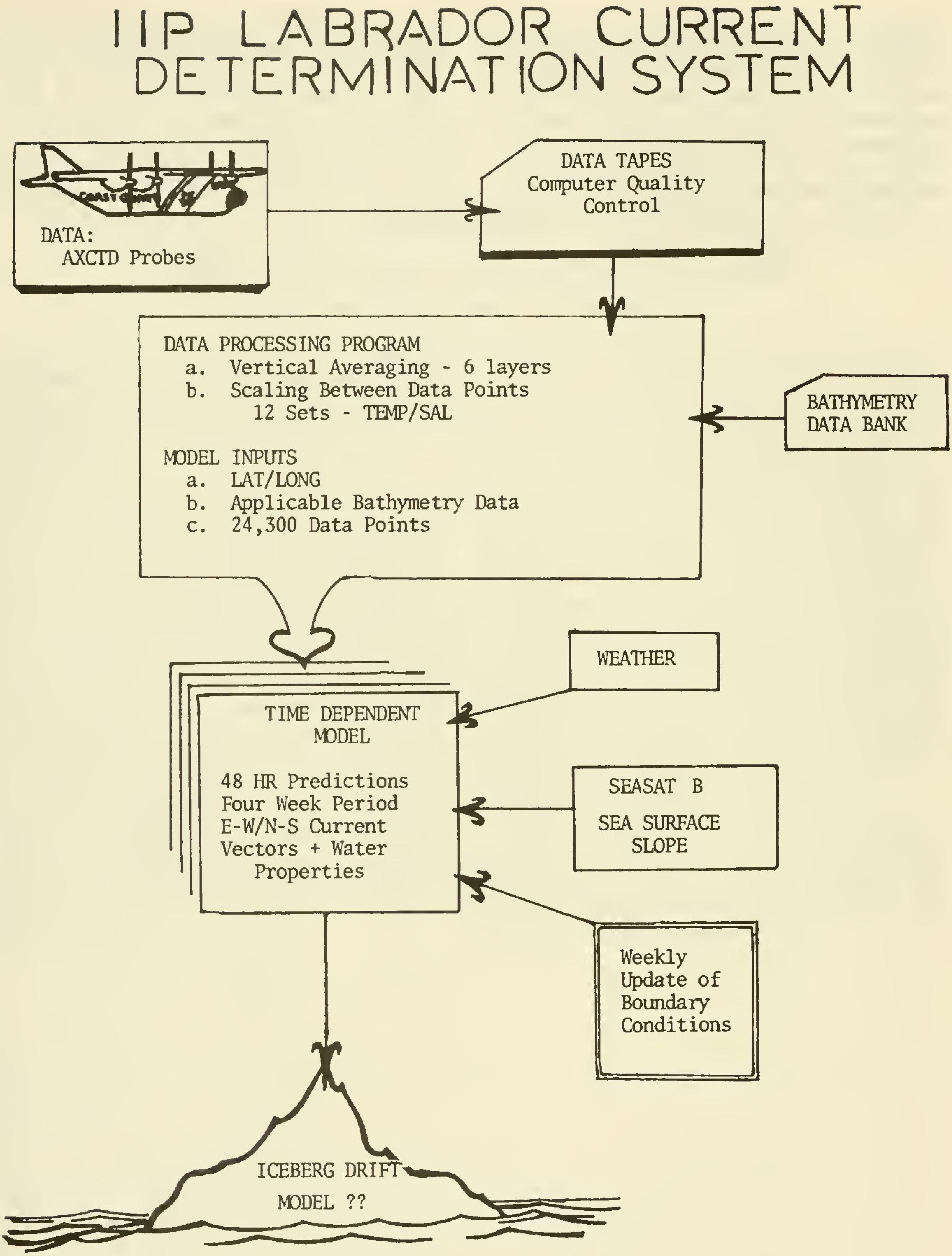

FIGURE B-3.—A suggested CIIP current determination system for the prediction of absolute currents in the Ice Patrol area. The shaded portions of the system have been completed.

being carried out by the Coast Guard Oceanographic Unit. This work is experimental at this time but looks promising. The vorticity model uses Gulf Stream velocities and the Grand Banks bathymetry as input. The physics of the model is based on the conservation of potential vorticity. Simply put, the Gulf Stream will follow the bathymetric contours to a greater or lesser degree depending on its velocity and velocity shear, and hence its vorticity. Thus, it is possible that the Gulf Stream's location throughout the Grand Banks region can be determined from points along the eastern boundary of the Ice Patrol region. What this information might provide is a predictive updating of the Gulf Stream's entering location into the Labrador Current Model area. Consequently, a data updating flight to the southern boundary might be eliminated.

APPENDIX C

ICEBERG POPULATIONS SOUTH OF 48°N SINCE 1900

by Lieutenant H. Gregory KETCHEN, USCG

International Ice Patrol has traditionally maintained counts of the number of icebergs crossing latitude 48° North. Icebergs south of this latitude are at best a potential and at worst a real hazard to the safety of primary North Atlantic shipping.

Table C–1 provides a breakdown by month of the estimated number of bergs crossing 48°N since 1900. This is an update of and provides some corrections to the table last published in the 1968 Ice Patrol Bulletin No. 54. The counts are broken down into two groups, 1900 through 1977 and 1946 through 1977. This separation is done because after World War II, aircraft reconnaissance became the primary method used by IIP for locating and tracking icebergs. Prior to that time, iceberg distributions were determined from surface observations made from Coast Guard cutters patrolling the southern limit of icebergs plus sightings by merchant and fishing vessels transiting the area. Since aerial coverage proved to be much more complete and frequent, data collected subsequent to 1945 represent more accurate counts.

Figure C–1 is a bar graph of the estimated numbers of icebergs crossing 48°N during each year since 1900. The variability in the record is obvious, with counts ranging from 0 bergs in 1966 to 1,587 in 1972. Monthly average counts for the full record and for recent years are depicted in figure C–2. Although a good indicator of relative importance of a particular month, those averages are biased by the high counts of a few extremely severe years. A better figure for the number of icebergs that might be expected to cross 48°N in a "typical" year is provided by the median of the counts. For the period 1900 through 1977 the median of the annual iceberg counts is 279, while the average is 383. For the period 1946 through 1977, the corresponding median is 107 while the average is 300.

Further analysis of the variability of iceberg distributions is provided in an article by C. W. Morgan titled "Long Term Trends in the Iceberg Threat in the Northwest Atlantic" published in the 1971 Ice Patrol Bulletin No. 57.

Season	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	TOTAL
1900	0	0	0	0	10	0	0	5	32	33	6	1	87
1901	1	1	0	0	1	0	0	4	13	29	22	6	77
1902	5	1	2	5	3	0	1	1	13	5	16	1	53
1903	0	1	0	0	0	2	400	166	151	52	23	7	802
1904	0	0	0	1	0	0	12	63	82	89	14	3	264
1905	2	0	0	0	3	2	168	373	109	100	50	9	816
1906	8	8	0	15	14	11	77	49	133	87	18	16	436
1907	0	0	0	0	0	1	11	162	248	138	64	11	635
1908	0	0	0	3	1	0	7	39	82	51	2	2	187
1909	20	15	3	0	0	55	147	134	321	181	121	45	1,042
1910	19	1	0	0	0	0	0	34	10	3	3	0	70
1911	0	0	0	0	0	8	41	112	72	77	21	40	371
1912	3	0	8	14	1	0	34	395	345	159	63	19	1,041
1913	0	0	3	0	2	4	37	109	292	71	14	4	536
1914	7	0	6	4	1	41	32	27	419	71	22	46	676
1915	52	13	1	6	14	72	67	96	97	71	28	17	534
1916	5	0	1	0	0	0	0	0	25	29	0	0	60
1917	0	0	0	0	0	0	13	3	3	9	10	0	38
1918	0	0	0	0	0	0	12	23	26	37	27	34	159
1919	22	1	14	3	3	4	5	25	75	56	26	36	270
1920	69	2	12	4	6	43	20	5	211	86	18	5	481
1921	18	19	10	4	17	5	43	210	198	175	53	24	776
1922	4	10	1	6	0	3	35	71	245	83	21	11	490
1923	6	27	21	0	0	3	28	65	83	42	10	3	288
1924	2	0	0	0	3	0	6	2	0	0	0	0	13
1925	0	0	0	0	0	3	5	8	58	22	13	0	109
1926	0	0	0	0	0	3	15	58	168	85	4	6	339
1927	2	3	1	0	4	10	26	93	153	95	5	3	395
1928	0	0	0	0	0	0	14	156	190	87	55	5	507
1929	0	4	4	0	0	0	45	332	460	376	107	1	1,329

TABLE C-1.—Estimated Monthly and Annual Counts and Averages of icebergs crossing 48°N latitude during the years 1900–1977.

Season	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	TOTAL
1930	0	0	18	12	14	116	87	89	101	62	3	1	503
1931	1	1	0	0	0	0	2	1	10	0	0	0	15
1932	0	0	0	0	0	1	43	321	90	58	1	0	514
1933	0	0	0	0	0	2	4	12	162	36	0	0	216
1934	0	0	0	0	1	0	0	245	228	87	14	1	576
1935	0	0	0	0	0	0	46	177	501	134	11	3	872
1936	0	0	0	3	0	0	0	8	14	0	0	0	25
1937	0	0	0	0	20	53	121	124	137	14	1	0	470
1938	0	0	0	0	2	3	38	212	286	110	13	0	664
1939	0	0	0	0	0	0	22	173	471	150	28	6	850
1940	0	0	0	0	0	0	0	0	1	0	0	0	1
1941	0	0	1	0	0	0	0	1	1	0	0	0	3
1942	0	0	0	0	C	0	30	0	0	0	0	0	30
1943	0	0	0	0	0	0	25	90	298	270	150	7	840
1944	0	0	0	0	0	0	31	319	213	106	30	1	700
1945	0	0	0	0	0	6	352	253	256	92	109	15	1,083
Total 1900-45	246	107	106	80	120	451	2,102	4,845	7,083	3,518	1,196	389	20,243
Average 1900-45	5	2	2	2	3	10	46	105	154	77	26	8	440
1946	0	0	0	0	0	2	67	98	168	88	7	0	430
1947	0	0	0	0	3	1	2	5	11	26	15	0	63
1948	0	0	0	0	0	0	60	210	185	68	0	0	523
1949	0	0	0	0	0	0	1	23	20	3	0	0	47
1950	0	0	0	0	0	12	61	183	135	58	7	0	456
1951	1	1	2	0	0	3	2	0	0	0	0	0	9
1952	0	0	0	1	0	0	0	12	2	0	0	0	15
1953	0	0	0	0	0	0	21	11	18	6	0	0	56
1954	0	0	0	0	1	16	47	165	65	16	2	0	312
1955	0	0	0	0	0	0	10	32	14	5	0	0	61

Season	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	TOTAL
1956	0	0	0	0	0	0	9	13	34	21	3	0	80
1957	0	0	0	0	3	43	41	172	265	288	113	6	931
1958	0	0	0	0	0	0	0	0	0	0	1	0	1
1959	0	0	0	0	0	0	14	266	180	186	43	0	689
1960	0	0	2	3	3	0	0	41	161	44	4	0	258
1961	0	0	0	0	0	6	60	30	16	1	0	1	114
1962	0	1	0	1	0	0	14	72	21	10	3	0	122
1963	0	0	0	0	0	0	4	20	0	1	0	0	25
1964	0	0	0	0	0	3	88	225	19	28	5	1	369
1965	0	0	0	0	0	1	19	33	22	1	0	0	76
1966	0	0	0	0	0	0	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	25	134	209	65	8	0	441
1968	0	0	0	0	0	0	0	104	44	60	14	4	226
1969	4	0	0	0	0	0	0	0	35	17	1	0	57
1970	0	0	0	0	0	0	0	5	2	70	8	0	85
1971	0	0	0	0	0	0	31	4	20	7	11	0	73
1972	0	0	0	0	0	40	185	501	559	225	48	26	1,584 (1,587)
1973	4*	0	0	6	54	110	134	212	159	151	19	1	850 (847)
1974	0	0	0	0	0	1	99	345	446	266	168	61	1,386
1975	1	0	0	0	0	24	41	10	20	5	0	0	101
1976	0	0	0	0	0	0	33	13	67	35	3	0	151
1977	0	0	0	0	0	3	7	12	0	0	0	0	22
Total 1946-77	10	2	4	11	64	265	1,075	2,951	2,897	1,751	483	100	9,613
Average 1946-1977	0	0	0	0	2	8	34	92	91	55	15	3	300
Total 1900-1977	256	109	110	91	184	716	3,177	7,796	9,980	5,269	1,679	489	29,856
Average 1900-1977	3	1	1	1	2	9	41	100	128	68	22	6	383

*The 1972 Season ended on September 4th. Three of these bergs actually drifted south of 48°N during the 1972 Ice Season. To provide statistical continuity they are included in the September monthly tabulation for the 1973 Ice Season.

Note:
1. Totals for 1900-45 are based mainly on ship reports.
2. Totals for 1946-1977 are based mainly on Ice Patrol aircraft reconnaissance.
3. Monthly estimates for the years 1939 and 1944 have been adjusted to reflect the total annual berg estimates as reported in the Bulletins for these years.

FIGURE C–2.—Monthly averaged number of icebergs crossing 48°N latitude for the two periods—1900 to 1977 and 1946 to 1977. The dashed lines indicate the most crossings for each month during the two periods. A record of 559 icebergs crossed 48°N during May 1972.

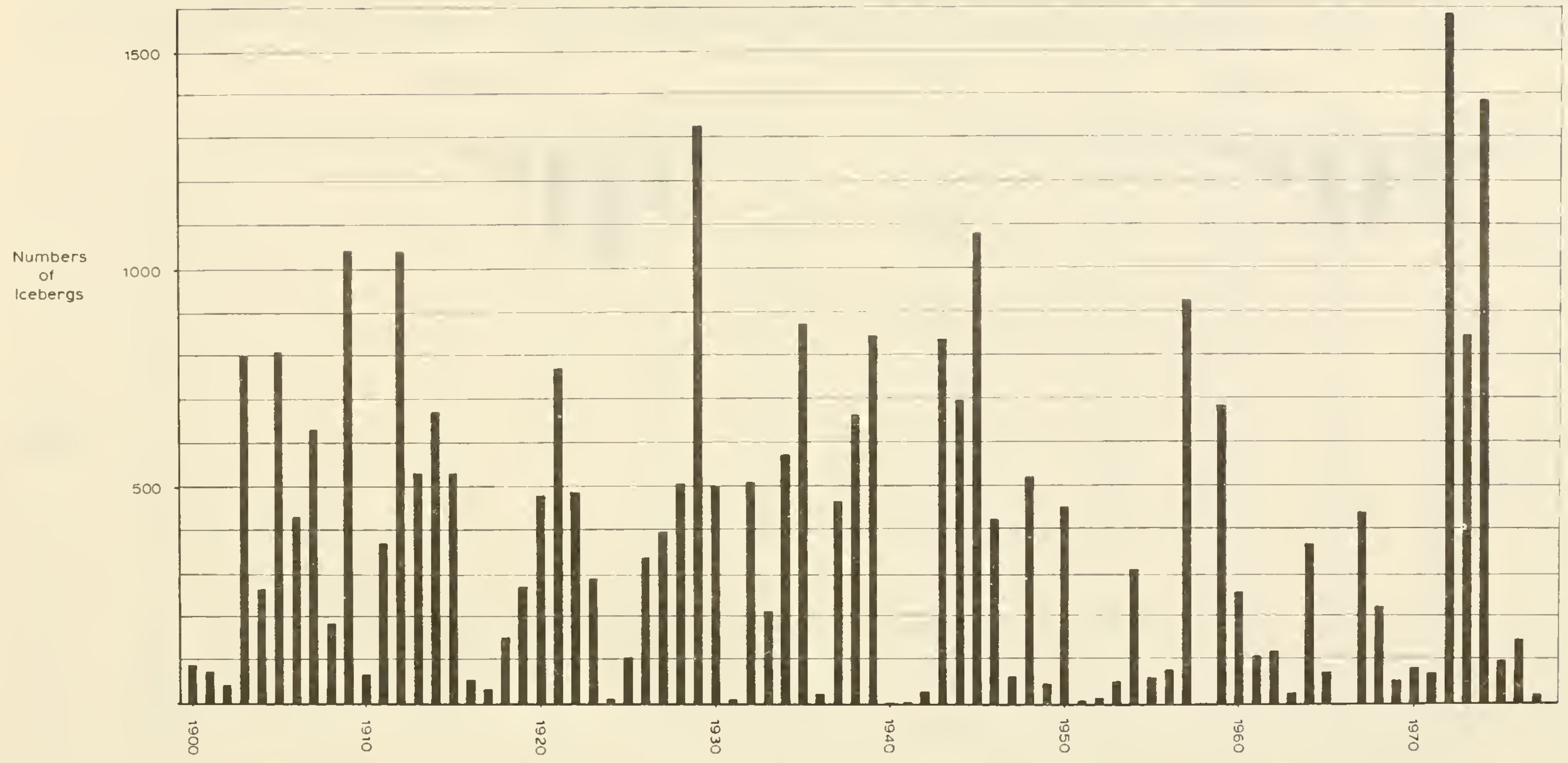

Figure C–1.—Estimated Numbers of Icebergs having crossed 48°N latitude during the years 1900 to 1977. The average for this record is 383 icebergs and the median is 279.

APPENDIX D

UNUSUAL ICEBERG SIGHTING

by Lieutenant H. Gregory KETCHEN, USCG
and
Marine Science Technician First Class R. N. HILDENBRAND, USCG

Icebergs are carried into the North Atlantic Ocean on the cold waters of the southward flowing Labrador Current arriving on the Grand Banks off Newfoundland during the spring of the year. The icebergs that reach these latitudes have survived a drift in excess of 1000 miles—most having originated from west Greenland glaciers north of 69°N. As these bergs approach the major shipping lanes south of 48°N, they present a serious threat to trans-Atlantic shipping. The danger near the Grand Banks is increased by a number of factors including: the large volume of vessel traffic passing through this area, the high density of fishing vessels working these very productive fisheries, and the frequent occurrence of fog and intense storms typical of the area.

The southerly drift of most of these icebergs ends with their final deterioration in the warm waters of the North Atlantic Current. This current, running along the southern and off the eastern edges of Grand Banks, serves as a barrier preventing the further distribution of icebergs throughout the North Atlantic Ocean. Occasionally, under the right environmental conditions, some icebergs survive to drift through the North Atlantic Current reaching positions far from those expected to be the normal maximum drift limits. The Ice Patrol has maintained a record of most of the unusual ice sightings reported during this century and a few earlier reports. Figure D–1 shows the maximum mean iceberg limit and reported unusual iceberg sightings. Not all of these reports were confirmed. A few of them may have been sightings of objects mistakenly identified as ice or the positions erroneously recorded. Enough of the sightings were verified to show that on rare occasions icebergs can reach far beyond the normal limits.

Although the International Ice Patrol's area of responsibility is limited to the vicinity of the Grand Banks off Newfoundland, it maintains an interest in iceberg information and sightings from throughout the world. Mariners are encouraged to report any significant or unusual ice sightings to the Ice Patrol.

FIGURE D-1.—Maximum Mean Iceberg Limit and Reported Unusual Iceberg Sightings.

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